METABOLIC AND CARDIO RESPIRATORY RESPONSES BETWEEN TREADMILL AND ERGOMETER CYCLE

Dissertation submitted to

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In partial fulfilment of the

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CERTIFICATE

This dissertation entitled **"METABOLIC AND CARDIO RESPIRATORY RESPONSES BETWEEN TREADMILL AND ERGOMETER CYCLE"** is submitted to The Tamil Nadu Dr. M.G.R. Medical University, Chennai in partial fulfilment of the regulations for the award of M.D., Degree in physiology in the Examinations to be held during April 2016.

This Dissertation is a record of fresh work done by the candidate **Dr. C.THENDRAL**, during the course of the study (2013-2016). This work was carried out by the candidate herself under my supervision.

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DECLARATION

I solemnly declare that the Dissertation titled **“METABOLIC AND CARDIO RESPIRATORY RESPONSES BETWEEN TREADMILL AND ERGOMETER CYCLE”** is done by me at Thanjavur Medical College, Thanjavur.

The Dissertation is submitted to the Tamil Nadu Dr. M.G.R. Medical University, Chennai, in partial fulfilment of requirements for the award of M.D. Degree (Branch V) in physiology

Place: Dr. C.Thendral
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INSTITUTIONAL ETHICAL COMMITTEE

CERTIFICATE

Approval No. : 094

This is to certify that The Research Proposal / Project titled

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submitted by Dr. C. THENDRAL of

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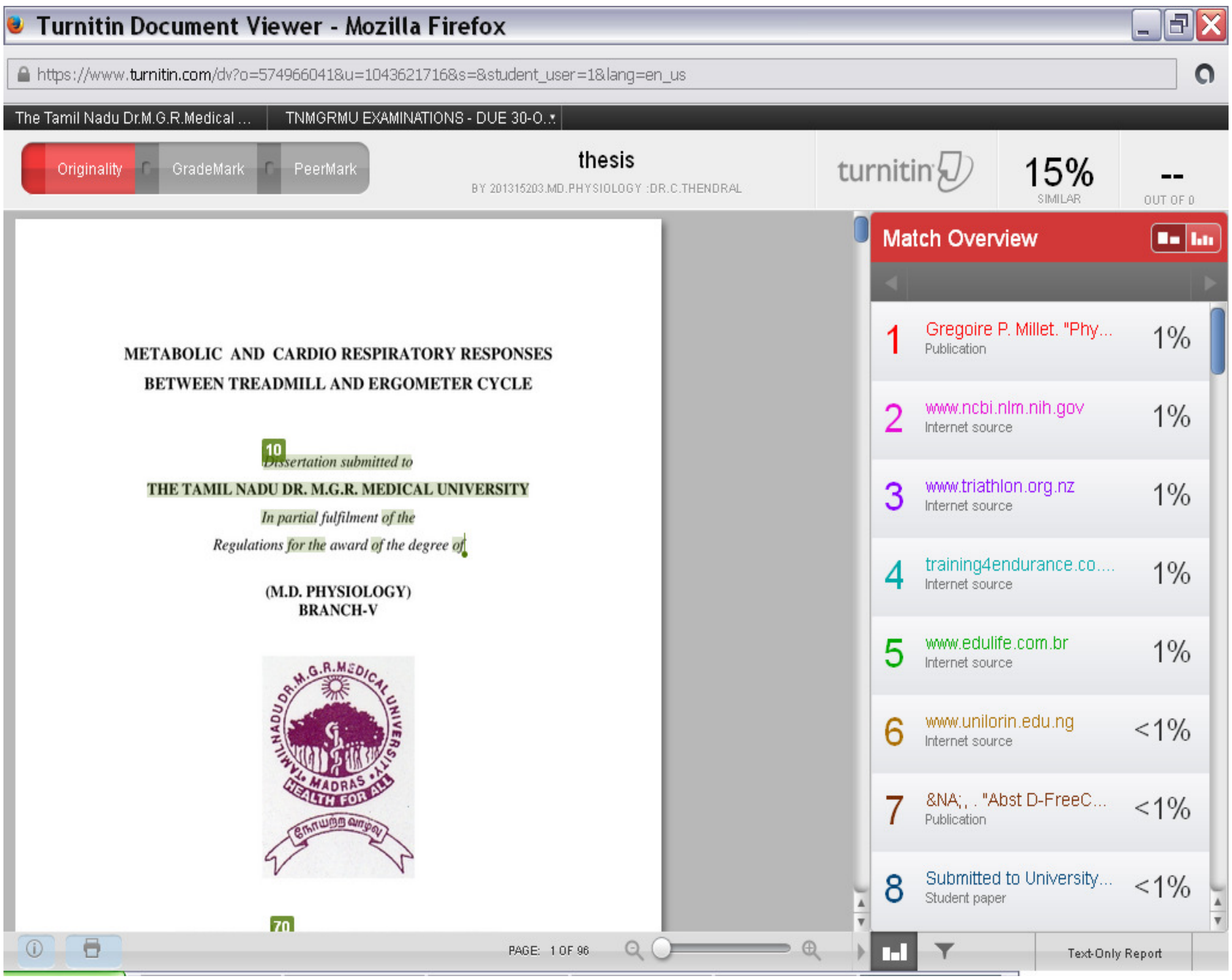


CONTENTS

METABOLIC AND CARDIO RESPIRATORY RESPONSES BETWEEN TREADMILL AND ERGOMETER CYCLE

Abstract

This study was aimed to determine the metabolic and cardio respiratory differences between Treadmill Running and Ergometer cycling. This study was undertaken in research laboratory of physiology department at Thanjavur medical college. 40 persons with the age group of 18-40 Years were taken as subjects. Informed consent was obtained. Experimental protocol was approved by Institutional Ethical Committee. The subjects were performed 3 discontinuous graded tests until exhaustion. In Bicycle, cycling was done for 2 mins at 60rpm. In Treadmill, for first 2 weeks subjects were asked to run at 4-8 mph for 20 minutes& from 3rd week to 12th week, 30 mins at 4-8 mph. Physiological variables such as Maximal heart rate, maximal oxygen consumption(VO_2 max) ,blood pressure and blood lactate were measured and compared in between Ergometer Cycling and Treadmill Running. The results were statistically analysed.The treadmill group showed higher maximal heart rate &maximal oxygen consumption. Whereas the ergometer cycle group showed higher systolic blood pressure response and higher blood lactate values than treadmill group. On the other hand, treadmill exercise produces less hemodynamic stress on cardiovascular system.

Keywords

Maximal oxygen uptake, anaerobic threshold, maximal heart rate.

INTRODUCTION

For those who strive to achieve and maintain a high quality of life, it must be recognized that Physical activity is vital to optimal health. Numerous studies have found that an association between physical activity, health and an improved quality of life in several ways.

Physical fitness is generally achieved through correct nutrition, exercise, hygiene and rest. The benefits of exercise are well established. It is well known that regular exercise reduces the incidence of stroke, hypertension, type 2 Diabetes mellitus, colon and breast cancer and Obesity [(1)].

In addition to prolonging the quantity of life, physical exercise enhances the quality of life by improving respiratory and cardiovascular functions; increasing feeling of well being, increasing performance of work, decreasing anxiety, stress and depression and reducing total body fat, Cardiovascular morbidity[(2)] .

Exercise is inevitable to keep our health in good status. The recommendations from the ACSM and AHA regarding guidelines for physical activity suggest that all healthy adults between age group of 18-65 need moderate intensity aerobic exercise for a minimum of 30 minutes 5 days per week[(3)].

Aerobic exercises include walking, jogging, running, cycling, swimming and skating. Indoor aerobic exercise include treadmill, bicycle ergometer, elliptical trainer, stair climbing, etc[(4)].

In the modern busy life, the bicycle ergometer and treadmill exercises are the commonest indoor aerobic exercises. Treadmill exercise is similar to walking and running and ergometer cycle is similar to cycling. These tools are used not only for maintain physical fitness and also for exercise testing[5]. Because exercise is the most common physiologic stress and it causes major demands on the cardiovascular system[6] .

Exercise testing is a noninvasive test to evaluate cardiovascular responses to exercise. Despite the many advances in technology for the diagnosis and treatment of cardiovascular diseases, the exercise test remains a very important diagnostic modality.

Three types exercises can be used to exercise stress test; isometric, dynamic, and a combination of two. So many modalities have been used to provide dynamic exercise for exercise testing like escalators, steps and ladder mills[5].However the bicycle ergometer and treadmill are the most commonly used dynamic exercise devises[7]. Not only for excise testing and maintenance of physical fitness, nowadays these are the most common modalities used to determine aerobic capacity of an individual. VO_2 max is a measure of maximal capacity of cardiorespiratory system to obtain, utilize oxygen to meet energy need of muscle contraction[8].

Hence Aerobic capacity is a measure of oxygen delivery and utilization, it is the most reliable and influential prognostic [9].

Direct measurement of maximal oxygen consumption needs an expensive laboratory for gas analysis. Hence various predictive tests can be used to evaluate cardiorespiratory fitness, these include treadmill walking, running and sub maximal ergometer cycling[(10)]

Besides Vo_2 max, anaerobic threshold is also a powerful marker in evaluation of physical fitness and its application in exercise testing is useful in gaining information regarding cardiovascular functions. Its elevation during exercise is highly correlates with intensity of work.

Thus the increased use of both exercise modalities has escalated the need to compare their relationships between them.

The purpose of the study was to compare maximal oxygen consumption, maximal heart rate, blood pressure response and blood lactate levels in treadmill and ergometer cycling exercise. Thus the aim of this study is to provide a synopsis of literature concerning the physiological differences between treadmill running and ergometer cycling and also by comparing physiological variables such as maximal oxygen consumption, maximum heart rate, blood pressure and anaerobic threshold, this study aims to identify the effects of exercise modality on the mechanisms of adaptation.

The hypothesize for this study is (i)treadmill running will evoke maximal oxygen consumption and maximal heart rate response,(ii)systolic blood pressure will be higher during cycle ergometer exercise than during treadmill exercise (iii higher blood lactate value in ergometer cycle.

REVIEW OF LITERATURE

Exercise physiology is the study of how the human body responds and adapts to physical stress under either acute or chronic exercise[11].

The origins of exercise physiology begin in early Greece. The great biblical empires David and Solomon were very much involved in exercise and sports.

Sushruta, an Indian physician believed that a sedentary life style contributed to obesity. He promoted the influence of different modes of exercise on human health and disease[11].

Galen the most well known physician wrote detailed descriptions about various forms and varieties of exercises[11].

Exercise physiology has gained great importance because of 1. Competitive sports and athletes have aroused a great deal of interest in exercise physiology all over the world,2. Role of exercise in prevention of cardiovascular diseases, 3.role of exercise stress tests in evaluation of the cardiovascular and respiratory systems, role of exercise in rehabilitation of the cardiac invalids[5,7]

Austin Flint one of the first American physician physiologist incorporated details about physiological responses to exercise in his physiology textbooks[11].

Edward Hitchcock ,Jr,professor at Amherst college devoted his academic career to scientific study of physical exercise and training[11]

PHYSICAL INACTIVITY

The merits of regular exercise are very well established. Even then in this modern era and busy life style, the percentage of inactive individuals are increasing. Most of the adults are spending their leisure time in front of television, mobile phone or with computer. It is perplexing to know why so many peoples, both young generation and old generation are leading sedentary life style despite of numerous health hazards. The lack of knowledge of regular physical activity, lack of social support and lack of access to activity programme are act as barriers that prevent the individual from exercising.

HAZARDS OF PHYCICAL INACTIVITY[11] ,

- Obesity
- Hypercholestremia
- Hypertension
- Atherosclerosis
- Myocardial infarction
- Type 2 diabetes mellitus
- Increases risk for colon cancer
- Increases risk for breast cancer
- Osteoporosis
- stroke

Therefore to lead a healthy life physical activity is must.

PHYSICAL FITNESS

Physical activity is an efficient stimulus for augmenting activity of skeletal muscle and cardiac functions.

Physical fitness

Physical fitness is an individualized index and it expresses the person's dynamic potential, functional metabolic components .

H.S.Harrison Clarke defines physical fitness as ability to carry out daily task with alertness without fatigue, with ample energy to enjoy leisure time pursuits, to meet unforeseen emergencies[12] .

Physical fitness can be obtained from regular physical activity, proper diet and proper rest.

PHYSICAL FITNESS AND ITS RELATIONSHIP TO THE DIMENSIONS OF HEALTH[12,13]

- **PHYSICAL DIMENSION OF HEALTH**

  To lead a healthy life we need to engage with regular physical fitness activities. Evidence suggests that if we remain physically fit, we may have lower risk of developing health problems.

- **EMOTIONAL DIMENSION OF HEALTH**

  Physical fitness activities can provide natural means of expending energy developed by our body's stress response.

In our busy life physical activities can provide the temporary emotional outlets.

Exercise is one of the excellent mechanisms for reducing impact of stressors.

- **SOCIAL DIMENSION OF HEALTH**

Exercising with others provides opportunities for more social interaction. The development of improved social skills needs contact with others. The improvement of the social dimension of our health requires communication with others

- **INTELLECTUAL DIMENSION OF HEALTH**

Physical fitness and physical activity have strong correlations with our ability to function intellectually. Persons engage with fitness activities definitely will feel mentally sharp after exercise.

COMPONENTS OF PHYSICAL FITNESS[13]

1. Muscular strength
2. Muscular endurance
3. Flexibility
4. Agility
5. Cardiovascular endurance.

MUSCULAR STRENGH

Muscular strength is important for our body to accomplish any type of work. Walking across campus, intramural sports and climbing stairs will maintain strength. Muscular strength can be increased by training activities.

MUSCULAR ENDURANCE

Muscular endurance is a component of physical fitness associated with strength. It results from the coordinated efforts of the circulatory and respiratory system.

FLEXIBILITY

The ability of movement of our joints through their natural range of motion is a measure of flexibility.

AGILITY

Agility or the ability to move quickly with frequent changes in direction or position enhances our performance in a variety of activities. Walking on ice – coverer sidewalks, dancing and completing many aspects of employment are improved by an adequately developed level of agility. Like other dimensions of physical fitness, agility can be maintained by sufficient opportunity for vigorous activity.

CARDIOVASCULAR ENDURANCE

Cardiovascular endurance forms the foundation for whole body fitness. Cardiovascular endurance increases our capacity to sustain a given level of energy production for a longer period. This dimension of physical fitness helps to work at greater levels of intensity.

NUTRITION AND PHYSICAL FITNESS[11]

Low energy expanding, highly sedentary life style and taking excess food are leads to poor physical fitness.

- Therefore to achieve physical fitness, active energy expanding life is essential.
- Regular active life style will enhance physical fitness. Balance diet, exercise and sleep will make the person physically fit.

EXERCISE

Exercise is a period of enhanced energy expenditure by skeletal muscles, which is met by many complex adjustments of metabolism, respiration, circulation and temperature.

Exercise have been classified into two categories; dynamic or isotonic and static or isometric.

TYPES OF EXERCISE [14,15]

Dynamic exercise

Exercise that involves isotonic muscle contraction is called as dynamic exercise. In isotonic contraction muscle length changes, therefore, external work is involved in this type of exercise.

Static exercise

Exercise that involves isometric muscle contraction is called as static exercise. In isometric muscle contraction muscle remains same; therefore no external work is involved in this type of exercise.

Grading of exercise

WHO CLASSIFICATION (1978) of grading of exercise[15,16]

Grade	Level	HR/min	O2 consumption L/min	Relative Load Index	METs
I	Light	<100	0.4-0.8	<25	<3
II	Moderate	100-125	0.8-1.6	25-50	3.1-4.5
III	Heavy	126-150	1.6-2.4	51-75	4.-7
IV	Severe	>150	>2.4	>75	>7

Relative load index-percentage of maximum o_2 utilization

MET-metabolic energy expenditure

-one MET is equivalent to resting o_2 uptake of 200ml/min for an average women.

PHYSIOLOGICAL RESPONSES TO EXERCISE

The primary changes in exercise are in oxygen uptake, cardiovascular, respiratory and changes at tissue level.

O_2 UPTAKE DURING EXERCISE

OXYGEN CONSUMPTION(VO_2) [14,15,16]

The energy for exercise is provided by increased fuel consumption, which is reflected in greater oxygen consumption.

Oxygen consumption during rest is 250 ml/min.

During exercise oxygen consumption increases to 15-20 times due to;

1) Increase in cardiac output

2) Increase in alveolar ventilation

3) Increase in capillary density

4) increase in RBC count

VO_2 MAX-MAXIMUM OXYGEN CONSUMPTION[11,17]

VO_2 max represents the greatest amount of oxygen that can be used by a person to produce ATP aerobically.

VO_2 max can be used as a measure of cardiorespiratory capacity.

It is the level of oxygen consumption beyond which no further increase in oxygen consumption occurs with further increase in severity of exercise.

VO_2 max of an individual determines the maximum aerobic work capacity and it is the best physiological indicator of aerobic capacity in man.

VO_2 max represents the highest attainable rate of aerobic metabolism.

VO_2 max increases during childhood, after that a gradual and steady decline takes place with the increasing work.

Avg VO_2 max in an adult is 3L/min

In trained athlete-5L/min

FACTORS AFFECTING VO_2 MAX [11]

Age

The VO_2 max increases during the childhood period and it reaches peak between 18-25 years. After the age of 25 years VO_2 max declines. The reason for early increase is due to growth of muscles, heart and lungs. Decline in older age is due to gradual reduction in cardiac efficiency with increasing age. However, studies have shown that one's level of physical activity determines VO_2 max.

Gender

VO_2 max values for men exceeds values of women by 15% to 30%.This gender difference in VO_2 max has generally been ascribed to differences in body composition and hemoglobin content.

Body Composition

Body mass differences contribute 70% of the differences in VO_2 max.

Training State

Training improves aerobic capacity between 6% and 20%.The most sedentary individuals attain largest VO_2 max improvement.

VO_2 max Predictions(10,18)

Directly measuring VO_2 max needs extensive laboratory equipment and trained personal.

Therefore, various predictive tests can be used to evaluate aerobic power. These include measures related with performance, like walking or running or measurement of heart rate during exercise and predicting VO_2 max.

HEART RATE PREDICTIONS OF AEROBIC POWER(11,19)

Commonest indirect method to predict VO_2 max on a bicycle or treadmill is by use of linear relationship between heart rate and oxygen uptake.

CRITERIA FOR ESTABLISHING VO_2max[6,16]

1. O_2 consumption reaches plateau

2. Achievement of maximum heart rate

3. Respiratory quotient(RQ) increases to more than 1.15.

4. Blood lactate concentration of 8 to 12 mmol L-1

5. Heart rate over 90% of the maximal HR.

OXYGEN DEFICIT AND O_2 DEBT[15,20]

Exercise period can be divided into three phases;

1. Adaptation phase

2. Steady phase

3. Recovery phase

Adaptation phase refers to first 2 to 4 mins of exercise during which oxygen consumption increases linearly and reaches maximal oxygen consumption.

At this stage VO_2 max is much less than the oxygen demand, therefore oxygen deficit is established at the beginning of exercise.

Steady phase of muscular exercise is characterized by a VO_2max. During this phase excess energy requirement is dealt by anaerobic pathway.

Because of anaerobic release of energy in the muscles, blood lactic acid levels rise steeply.

Recovery phase –The period after cessation of exercise during which extra amount of oxygen is consumed.

The extra amount of oxygen consumed during recovery phase is called as O_2 debt.

CARDIOVASCULAR RESPONSES TO EXERCISE[14,15,16,17]

The primary cardiovascular response during exercise is to meet the increased energy demand. This is achieved by

1. Increase in the cardiac output,
2. Increase in the skeletal muscle blood flow,
3. Redistribution of blood flow in the body
4. Changes in blood pressure
5. Changes in blood volume

INCREASE IN CARDIAC OUTPUT

Normal cardiac output is about 5-6 L / min.

Cardiac output is increased during exercise due to increase in heart rate and increase in stroke volume.

Factors contributing to increase in heart rate during exercise are:

- Increased sympathetic discharge
- Peripheral reflexes
- Metabolic and humoral factors
- Increased temperature

Increase in stroke volume due to;

- Intrinsic auto regulation /Frank-Starling mechanism
- Extrinsic regulation/autonomic and neural mechanism

Factors contributing to increase in stroke volume

- Increased venous return –
  - a) Vigorous muscular contractions promote flow of blood towards the heart.
  - b) Increased depth and frequency of respiratory movements, draws blood into thoracic veins.
- Starling law
- Increased sympathetic activity
- Stimulation of afferent nerve endings by metabolites.

INCREASE IN SKELETAL MUSCLE BLOOD FLOW

Resting; 3-4 ml/100gm/min

During exercise muscle blood flow can increase up to 20 times due to

- Metabolic control-CO_2, lactic acids, potassium ions and hydrogen ions accumulation.
- Autonomic control-sympathetic cholinergic fibers.
- Humoral control-adrenaline through beta receptor mediated vasodilatation.

REDISTRIBUTION OF BLOOD FLOW

- Coronary blood flow

  - During exercise, it increases by 5 times due to

- Sympathetic stimulation, via increased cardiac output, increase in mean arterial pressure and increased activity of heart.

- Coronary vasodilatation through catecholamine, hypoxia, fall in blood pH, ATP and ADP.

- Visceral blood flow is temporarily curtailed, renal blood flow and splanchnic blood flow decreased.

- Adipose tissue blood flow is increased by 4 times, this helps to mobilize fatty acids from triglyceride stores to exercising muscles.

BLOOD PRESSURE CHANGES[14,21]

Systolic blood pressure increases due to sympathetic induced cardio acceleration.

In mild to moderate exercise, diastolic pressure increases.

In moderate to severe exercise, diastolic pressure decreases.

BLOOD VOLUME CHANGES

Blood volume decreased during exercise resulting in haemoconcentration due to following reasons;

- Increased hydrostatic pressure in capillaries,

- Increased osmotic pressure due to accumulation of osmatically active metabolites

RESPIRATORY RESPONSES TO EXERCISE[11,14,15,16]

- Increase in pulmonary ventilation

At rest ,pulmonary ventilation is 6 litres per min.

During exercise it increases by 20-25 times via following mechanisms,

1. Psychic stimuli
2. Afferent impulse from proprioceptors
3. Stimulation of carotid bodies
4. Accumulation of lactic acid
5. Increased body temperature

- Increase in oxygen uptake in the lungs

1. Increased pulmonary perfusion
2. Increased alveolar capillary Po_2 gradient
3. Increased pulmonary diffusion capacity

OTHER CHANGES

Increased blood flow in the tissues, increased Po_2 gradient, increased oxidative metabolism, right shift of O_2-Hb dissociation curve leads to extracting large amount of O_2 from blood &utilizing O2 in the exercising tissue.

Endocrinal Responses

Catecholamine, Glucagon, Antidiuretic hormone, ACTH and cortisol, Endorphin-increased during exercise.

PHYSIOLOGICAL MECHANISMS ASSOCIATED WITH DIFFERENCES BETWEEN CYCLING AND RUNNING

Ventilatory Responses[22,23]

Literatures documented differences in ventilatory responses to exercise between running and cycling.

- Exercise –induced arterial hypoxemia more frequently noticed in cycling than running.
- Ventilatory kinetics more decreased in cycling.
- Pulmonary diffusing capacity was more decreased in cycling(96)
- Ventilation was more impaired in cycling than running.(147)

Central and peripheral blood flow[24,25]

- Higher stroke volume during treadmill running than during cycling.
- Lower cardiac output in cycling can be due to reduced venous return.
- Differences in peripheral blood flow in the lower extremities.
- Running induces pro inflammatory processes, that itself increases muscle blood flow.
- Decrease in lower limb blood flow immediately after exercise in cycle than running.

Muscle Recruitment Patterns[26]

Mainly plantar flexors are involved in running and quadriceps in cycling.

Differences in muscle recruitment could be the reason for differences in anaerobic threshold (AT) during cycling and running.

In cyclists muscle fiber recruitment depends upon pedaling rate.

Pedaling frequency[27]

Greater difficulty in cycling compared with running.

Greater muscular strength needed for cycling.

Neuromuscular Fatigue[22]

Type of muscle contraction is different between running and cycling, neuromuscular fatigue originates from different sites depends upon mode.

Isometric strength loss is correlated with the duration of exercise in running, not so in cycling.

Central fatigue was noticed after prolonged running. Neural input to the muscle is reduced after prolonged cycling and failure of peripheral contractile mechanisms.

EFFECT OF AEROBIC TRAINING[11,17,28]

Training is aimed to increase the resistance to fatigue.

Aerobic training causes improvement in VO_2max, thereby promotes energy generating system aerobically.

Aerobic training raises threshold for lactic acid production.

Effect of training on metabolism

Aerobic training provides intracellular changes, that lead on to improved capacity of muscle fiber to generate ATP aerobically.

Aerobic training increases mitochondrial number and size in trained muscle. This helps to produce ATP by oxidative phosphorylation.

Effect of training on Fat metabolism:

Regular exercise improves an individual's ability to oxidize fatty acids within active muscles during exercise.

Greater blood flow within trained muscle and large quantity of fat mobilizing enzymes promotes lipolysis.

Thereby allowing the enduranance athletes to exercise at higher level of submaximal exercise without experiencing fatiguing effects of glycogen depletion compared with untrained person.

Effect of training on Carbohydrate metabolism

Aerobic exercise training improves oxidizing capacity of carbohydrates. Greater mitochondrial capacity and glycogen storage of trained muscle are the basis of enhanced capacity for carbohydrate metabolism.

Effect of training on Protein metabolism

Aerobic exercise training enhances protein turn over, increases muscle amino acid production.

SYSTAMIC EFFECTS OF TRAINING[11,14]

Cardiovascular effects

Heart size

Aerobic training for long term increases heart mass and left ventricular end diastolic volumes. This is characterized by thickening of walls and increased size of the left ventricular cavity.

Plasma volume

Training causes increase of plasma volume up to 20%.This enhances thermoregulatory and circulatory dynamics and favors oxygen delivery to muscle during exercise. This increase of plasma volume with training contributes to eccentric hypertrophy of heart.

Stroke volume

For untrained persons, only a mild increase in stroke volume occurs in the transition from rest to exercise. But for trained athletes stroke volume increases to 50% to 60% above resting values.

Heart rate

Reduction in heart rate during submaximal exercise accompanies the large stroke volume of elite endurance athletes.

Cardiac output

Most significant change in training is increase in cardiac output.

Oxygen extraction

Aerobic training enhances the quantity of oxygen extraction from blood during exercise. Increase in a-vo2 difference is produced by effective distribution cardiac output to exercising muscles and improved capacity of muscle fibers to oxygen metabolism.

Blood pressure

Aerobic training decreases systolic and diastolic blood pressures. Most apparent effect occurs for systolic pressure, mainly for hypertensive subjects.

RESPIRATORY EFFECTS

Aerobic training enhances oxygen delivery and extraction. Oxygen carrying capacity of blood improves with training.

INSULIN SENSITIVITY

Aerobic training improves sensitivity to insulin. Thereby promotes transport of glucose into the muscle.

ADVANTAGES OF TRAINING[11,17,28]

- Aerobic training promotes athletic performance by enhancing muscle oxidative capacity.
- Regular exercise slows the aging process.

- Aerobic training decreases risk for coronary artery disease, because training causes many positive cardiovascular adaptations that halts the onset of CAD.
- Aerobic training increases HDL and decreases LDL and triglycerides.
- Reduces resting systolic and diastolic blood pressure.
- By increasing caloric expenditure, aerobic training decreases total body fat. Thereby it prevents obesity.
- Helps to control blood glucose levels.
- Promotes psychological health.

BIOENERGETICS

Definition[28]

Bioenergetics is defined as energy transformation in living organisms.

Energy[29]

The term energy denotes the capacity to do work and there are two categories;

Kinetic and potential.

The first law Thermodynamics-the conservation of energy. This law states that energy can neither be created nor destroyed, but it can be changed from one form to another. In our body energy released through chemical compounds exchanging atoms or bonds between various molecules.

The cell as a chemical engine

The free energy required by the cell is derived from the potential energy stored in the food stuffs and from the radiant energy of the sun. All chemical compounds posses' energy which can be released under appropriate conditions. The energy released by chemical reactions in the cell is used chiefly to drive other reaction.

AEROBIC AND ANAEROBIC METABOLISM[11,28]

Aerobics refer to the use of oxygen to get energy to do an endurance type of activity. Aerobic metabolism generates energy, CO2, and water. This metabolism mainly used at rest, and during longer duration, lower intensity physical activity.

Anaerobic refers to production of energy with out the use of oxygen. Only carbohydrates used to obtain energy anaerobically. Anaerobic metabolism generates energy ,CO_2 and also lactic acid. This lactic acid production leads to increase in blood and intramuscular acidity. Acidity negatively affects activity of some enzymes, and causes decrease in production of energy.

ADENOSINE TRIPHOSPHATE; ENERGY CURRANCY[11,17]

The most important of the high energy compounds is adenosine triphosphate.This act as a special carrier to provide required energy for cellular functions and it act as energy currency.

ATP+H_2O--------ADP+Pi+ ENERGY

Energy

ADP+Pi------------------ATP

A limited currency

Our body stores ATP only a limited quantity, so it must be resynthesized continually.

PHOSPHOCREATINE; ACT AS A ENERGY RESEVIOR

Another high energy compound –phosphocreatine(PCr) a phosphate compound provides energy for ATP synthesis. Storage capacity of the cell for PCr is more than ATP.

The hydrolysis of phosphate does not need oxygen, begins at the onset of exercise, and attains maximum in about 8 -12 secs.

ENERGY PATHWAYS[11,17,28]

Three common pathways for ATP generation

i. Phosphagen or ATP-PC system
ii. Lactic acid system
iii. Aerobic oxidation

Phosphagen system :

Sometimes called as alactic anaerobic metabolism. This source of energy production used preferentially in very short duration, high intensity activities. ATP-PC can provide energy for less than 10 seconds of maximal activity. This system neither uses oxygen nor produces lactic acid, therefore this system is called as alactic anaerobic.

Lactic acid system:

This system involves glucose or glycogen or both, hence known as glycolysis. Whenever the demands for ATP go beyond the capacity of the phosphagen and aerobic system, anaerobic glycolysis is used. This rapid glycolysis can provide supplemental energy quickly at the cost of lactic acid production. It does not utilize oxygen but results in the production of lactic acid, so known as lactic anaerobic system

Aerobic oxidation:

The aerobic pathway is one of the most complexes of these pathways and utilizes more substrate preparation and time. Benefits of this system is provision of large amount of ATP (more than 400 ATP through beta oxidation of fat and 38 ATP through glucose)

METABOLISM DURING MUSCULAR EXERCISE

Immediate energy-phosphocreatine system

Short term energy-Lactic acid system.

During intense exercise energy is provided by mainly intramuscular glycogen stores. Because of inadequate oxygen supply, hydrogen formed in this rapid glycolysis can not be oxidized. Hence hydrogen ion combines with pyruvic acid which in turn reduced to lactic acid.

LONG TERM ENERGY

Aerobic system

This system provides greatest energy transfer, mainly when exercise duration exceeds 2 -3 mins.

ANAEROBIC EXERCISE RESPONSE[11,28]

Oxygen Deficit and Excess Post exercise Oxygen Consumption

A.V.Hill coined the term oxygen debt.

At the beginning of exercise whether light or heavy, there is a need for additional energy. There is a lag between oxygen supplied and utilized during initial stage of exercise. This difference between required and supplied and utilized is called as oxygen deficit. This term was coined by A.V.Hill.

Excess post exercise oxygen consumption(EPOC)

Oxygen consumption above resting values known as EPOC.

Factors responsible for EPOC are :

1. Restoration for O_2 stores

2. Restoration of ATP-PC stores

3. Elevated temperature

4. Elevated cardiovascular –respiratory function

5. Lactate removal

Formation of Lactic acid[11,17,28,30]

- When exercise intensity increases, breakdown of ATP and phosphocreatine is not sufficient to meet the required energy. It is met by accelerated breakdown of glycogen to glucose and then to pyruvic acid.
- Pyruvic acid resulting from glycolysis is either incorporated into oxidative metabolism via the Krebs cycle or is converted to lactic acid.
- This rise in lactate is believed to occur due to increased rates of glycogen break down and increased conversion of glucose to pyruvate.
- When exercising above the lactate threshold blood lactate levels will often continue to rise over time.

As lactate levels rise there is an increase in hydrogen ions, which impairs contractile process.

Exercise physiologist quotes that lactate itself does not cause fatigue; it is actually used as a fuel within aerobic metabolism, where it can be oxidized to pyruvate or glucose for oxidation

Therefore while lactate levels correlate with endurance exercise performance, instead of negatively interfering with performance, by causing fatigue it appears to be a marker for other processes occurring in the muscle that are real culprits of fatigue.

Historical Perspective on Lactic Acid Formation

In nineteenth century, Louis Pasteur noted that oxygen lack results in the formation lactic acid.

Otto Meyerhof declared glycogen as the precursor of lactic acid.

Claude Bernard, who reported that the amount of lactate in muscle was proportional to previous exercise.

In early 1900s research on understanding the biochemistry of energy metabolism resulted in the understanding of the role of lactic acid and its involvement in providing energy for muscle contraction.

In 1875 Pfluger reported that muscle contraction could occur in an anaerobic environment, and the metabolic pathway that can provide energy under these circumstances recognized as glycolysis.

LACTIC ACID PRODUCTION[28]

Lactic acid always produced by red blood cells, kidneys ,tissues within the eye. Resting and exercise values depend upon the balance between production and clearance. When production exceeds clearance, lactate is said to accumulate.

FACTORS DETERMINE PRODUCTION OF LACTIC ACID[11,28]

1, Muscle contraction

2. Enzyme activity

3. Muscle fiber type

4. Sympathetic nervous system activation

5. Insufficient oxygen

LACTATE CLEARANCE[17,31]

Primarily by three processes: Oxidation, gluconeogenesis and transamination.

Intracellular lactate shuttle

Movement of lactate by monocarboxylate transporters 1(MCT) between cytoplasm and mitochondria.

Inside the mitochondria lactate is oxidized to pyruvate, and pyruvate proceeds aerobic metabolism'

Extracellular lactate shuttles

Involves movement of lactate between tissues.

MCT1 and MCT4 move the lactate both out of and into tissues.

From bloodstream lactate can also circulate in to cardiac cells and during heavy exercise lactate is one of the preferred fuel of the heart.

Lactate can also transported to the liver, there it is converted to glucose through process of gluconeogenesis.

LACTATE –A GLUCONEOGENIC PRECURSOR [6,31]

Although lactate can contribute to muscle fatigue by inhibiting other enzymes of glycolysis and by increasing ventilation, it also serve as an important energy source and it acts as an important precursor for glycogen during exercise.

ANAEROBIC THRESHOLD[31,33,34]

Wasserman and Mcllroy proposed the term anaerobic threshold.

Definition

The exercise intensity at which blood lactic acid begins to accumulate above the resting concentration is known as anaerobic threshold or lactate threshold or onset of blood lactate accumulation.

- AT is a point during exercise when muscle fiber turns to anaerobic metabolism as an source of energy.
- At higher levels of exercise, oxygen demand may go beyond the capacity of cardiovascular system in delivering oxygen. Under such circumstances, glycolysis progress in the cytoplasm until pyruvate is formed.
- In untrained persons anaerobic threshold occurs at 50% to 60% of maximal oxygen consumption, but in trained persons occurs at 65% to80% of maximal oxygen consumption.
- On increasing exercise intensity associated with more amount of hydrolysis of ATP and production of lactic acid, resulting in metabolic acidosis.

- Once lactate is formed, it is buffered by bicarbonate system, causes more CO2 excretion, resulting in hyperventilation.

- Below AT, CO2 production is directly proportional to consumption of oxygen. Above the AT, production of carbon dioxide exceeds oxygen consumption.

- Being acid, it dissociates into hydrogen ions and lactate. Increased acidity affects force generation of the muscle through decreasing myosin ATPase activity, impairing of binding of calcium to troponin and affects the ability of sarcoplasmic reticulum to release calcium.

- Lactate levels are found to be higher than resting values at work rates of 55-70% VO_2 max.

Determination of anaerobic threshold[32,34]

- Anaerobic threshold can be measured by using blood samples (capillary sampling-fingertips or earlobe), arterial /venous blood can be used.

- For measuring AT using blood lactate levels either application of a fixed point at 4mmol.L-1 or the initial rise in lactate above resting baseline value can be used.

- Enzymatic method is the method of choice. Other methods are gas chromatography, photometry can be measured non-invasively through ventilatory threshold analysis.

- The departure in the linearity of the carbon dioxide, ventilation and abrupt increase in gas exchange ratio can be used as a determination of the metabolic acidosis.

The resting blood lactate level is 9-8mg per 100ml or 1-2 mmol l^{-1}.

During exercise the level may rise to 100 or even 200 mg per 100 ml or 11-22 mmol l^{-1}[32]

- The work rate above which blood lactate exceeds the resting value (1mmol.l^{-1}) known as anaerobic threshold or lactate threshold.

Anaerobic threshold and athletes[35]

Anaerobic threshold plays a major role in the assessment of athletic performance. Anaerobic threshold can be used to monitor adaptation to training and for prescribing various exercise protocols to determine VO_2 max.This is significantly related with athlete's endurance capacity. Researchers have reported that training causes increase in anaerobic threshold.

Increase in anaerobic threshold with training can enhance an individual's capacity to perform sustained sub maximal activities, which leads to improvement in quality of life.

MECHANISMS OF INCREASING AT[33,35]

- Biochemical alterations within skeletal muscle
- Improved oxygen delivery to exercising muscle
- Enhanced rate of lactate clearance
- Diminished catecholamine release after training

Orr et al expressed that limitation of exercise is by multifaceted interplay between cardiac, respiratory and specific group of muscles exercised and observed higher VO_2 max and anaerobic threshold in running than cycling[36] .

Kravitz et al, compared energy expenditure and VO_2 max during treadmill running and cycle ergometer. Results showed treadmill running is the modality of choice for individuals to improve cardio respiratory endurance[38] .

Klein et al compared ergometer and treadmill exercise responses in 140 patients and revealed that treadmill and cycle evoke different clinical and haemodynamic responses[38].

Bouckaert et al compared aerobic power in cyclists and runners completing incremental treadmill and cycling activity and reported 14% higher VO_2 max in treadmill running compared with bicycle ergometer[39].

Boileau et al in their study on oxygen consumption in normal children aged 8 to 14 years, and results showed that VO_2 max averaged from 7-11% higher during treadmill as compared to cycle ergometry[40].

Hambrecht et al made study on sensitivity of treadmill and cycle for detection of coronary artery disease and found that treadmill has greater sensitivity than cycle for detection[41].

Miles et al observed treadmill walking resulted in an 8% greater maximal aerobic power than during cycle ergometer exercise .They analyzed the involvement of small muscle mass and anaerobic metabolism resulted in lower aerobic power and higher blood lactate during cycling[42].

C.Abrantes et al analyzed metabolic and cardiorespiratory responses between treadmill and ergometer cycling. They found significant mode effect in heart rate and oxygen uptake. Treadmill protocol elicited higher heart rate and oxygen uptake[43].

Kenneth R.Turley et al provided two maximal treadmill and two maximal cycle ergometer tests to 46 children 7 to 9 years old (23 boys and 23 girls) and found that the treadmill resulted in a 9.4%, 11.1%, and 10.2%higher maximal oxygen consumption values than cycle ergometer in boys, girls, and the total population[44].

Martinez et al made physiological comparison of different modes and found the highest aerobic power and maximum heart rate was elicited by treadmill than cycling .Blood lactate level was lower in treadmill than cycle. They suggested that during cycling oxygen uptake is limited because of local muscle fatigue[45] .

Fabien A.Basset et al compared cardiorespiratory variables in runners and cyclists and concluded that treadmill subjects had higher HRmax valus and VO_2 max than cyclists[46] .

They showed the strong relationship between HR and VO_2 during either in treadmill or in cycle ergometer tests.

Moreira –da-costa et al found that VO_2 max was highest in the exercise mode that the athletes had trained in and they have reported a higher VO_2 max value in treadmill exercise for runners and cyclists respectively[47] .

Ravikiran kisan et al compared the effects of the treadmill and ergometer cycle on cardiovascular responses. They observed different responses in bicycle ergometer and treadmill exercise and noticed changes in blood pressure and heart rate more in treadmill[48] .

Hsia et al provided incremental exercise to 16 subjects with chronic obstructive pulmonary disease using cycle, linear treadmill and modified Bruce protocols. They observed the Peak VO_2 14%higher for treadmill, probably reflects the larger muscle mass involved in treadmill exercise, and anaerobic threshold was lower in cycle compared with treadmill testing reflects smaller muscle mass involved in cycling[49] .

J.L.Pannier et al studied cardio respiratory responses between treadmill and bicycle, and concluded that during maximal exercise, oxygen uptake and pulmonary ventilation reached higher levels on the treadmill than on the bicycle ergometer. The differences between VO_2 max values obtained on bicycle ergometer and on treadmill are influenced by the training conditions of the subject[50] .

Gregoire P.Millet et al described that submaximal running exercise induces higher oxygen uptake and energy expenditure than cycling at the same intensity.

Since the post exercise oxygen consumption is similar in cycling and running but lactate concentration was shown to be higher after cycling at the same submaximal intensity[22].

Kohrt et al compared VO_2 max of triathletes measured in both cycle ergometry and treadmill running. They assessed 13 triathletes and found that VO_2 max was significantly lower in cycle ergometry as compared with treadmill running [51] .

Maximal heart rate is generally reported to be slightly higher when obtained from an incremental treadmill test as compared with an incremental test in untrained subjects[52].

Scott et al reported that during a short bout at same intensity, total energy expenditure was similar between cycling and uphill running but the extent of aerobic and anaerobic energy transfer was different; the glycolytic component was 28% in cycling and 17% in running[53] .

G.A.McKay et al observed performance on bicycle ergometer and treadmill, confirmed that peak Vo_2 during bicycle ergometry is significantly less than VO_2 max attained in treadmill running[(54)] .

Walaa Mohamed Elsais et al studied physiological responses during both incremental cycling and treadmill exercise to volitional exhaustion .The results revealed that maximum oxygen uptake was significantly higher in treadmill as compared with cycle ergometer [(55)].

Montgomery et al showed VO_2max ranges from 52 to 58 $ml.kg.\ min^{-1}$ on the cycle ergometey, but VO_2 max ranged 54 to 62 $ml.kg.min^{-1}$ on the running treadmill. According to Montgomery, running treadmill will elicit VO_2 values that are 10% higher than the cycle ergometer[(56)] .

Helan Carter Andrew studied the physiological effects of oxygen uptake, comparison was done between treadmill and cycle group .Study results showed treadmill is a high energy expenditure instrument compared to ergometer cycle[(57)]

Miles et al(O) studied the cardiovascular, metabolic, and ventilator responses of women to equivalent cycle ergometer and treadmill exercise and reported that treadmill walking resulted in an 8% greater maximal aerobic power than cycle ergometer exercise. They reported that blood lactate concentrations were higher and maximal heart rates were lower during cycle ergometer exercise[(42)] .

Medelli et al compared the physiological effects between cycling and running and their results showed that pulmonary ventilation, heart rate and VO_2 reached the highest values on treadmill. They indicated that the amount muscle mass, the type and the distribution of active motor units involved in each exercise test might be at the origin of these differences[58] .

Smith et al conducted study about 1) distribution of lactate between plasma and red cells, 2) lactate threshold, in males who performed two progressive load test to volitional fatigue on a cycle ergometer. The results showed that whole blood lactate ,RBC lactate, and plasma lactate were increased .However ,the RBC :Plasma lactate ratio remained at the resting level, suggested that 1 min is adequate for equilibrium of lactate between the plasma and RBC[59] .

Astrand-rhyming nomogram showed a linear relationship between oxygen consumption and heart rate[60] .

Niels Uth et al suggested that a relationship between VO_2 max and the HR max-to-HR rest ratio .Their observation based on Fick principle and literature data for max-rest ratios for HR, stroke volume and arterio-venous O_2 difference suggested that VO_2max may be estimated by multiplying HRmax.HRrest-1 by a factor of about 15. They concluded that the HR max-to-HR rest ratio may provide a tool for estimation of VO_2max [19] .

Wicks et al conducted a analysis from data collected from 60 studies which were published in authorized journals and they investigated the relationship of various heart rate measures and VO_2 max. They noticed a strong relationship between HR index and oxygen uptake[61] .

Collin et al observed the relation of heart rate and maximal oxygen consumption in 15 male weight lifters, and reported the HR and VO_2 linear relationship during high resistance exercise[62] .

Young Joo Kim et al provided graded exercise tests on cycle ergometer and Treadmill and noticed the blood pressure response in each mode.

They concluded that SBP response is stronger in cycle ergometer than in treadmill. Therefore there is a possibility of cycle ergometer to induce a greater workload burden to cardiovascular system than treadmill [63].

Reed J found blood pressure reactivity is primarily mode dependant. He documented blood pressure response in females in both modes and blood pressure increased more in cycling. Cycling is associated with greater non exercising muscle vasoconstrictive responses, decreased mechanical efficiency and decreased vagal stimulation[64] .

C.C.Christensen observed the physiological responses to bicycle and treadmill exercise in COPD patients. They indicated that treadmill exercise resulted in higher oxygen uptake than cycle ergometer and plasma lactate levels were increased during cycling. This is explained with the use of larger muscle groups and familiarity with walking and running[65] .

Kurl et al conducted study about blood pressure response to exercise stress test in 1026 healthy male subjects .They have noticed that excessive elevation of SBP during exercise and persistent rise after 2 mins exercise were strongly associated future stroke, so they recommended exercise systolic blood pressure testing as a important tool for identification of future stroke[66] .

Moghiseh et al observed the association of VO_2 max and heart rate in casting industry workers .Their results showed that there was strong correlation between heart rate and VO_2max and revealed that heart rate could be used as a prediction measure to estimate VO_2 max[67] .

Arts et al examined the relationship between % Wmax,%VO_2max and % HR max in male cyclists and showed a linear relationship between power output,oxygen uptake and HR in male athletes [68].

Esposito F et al studied the physiological demands, HR versusO_2 uptake relationship during treadmill exercise and during soccer activities. Their results showed that HR measured during soccer exercise.

Training improves the metabolic capability and oxygen transport to the muscles there by affects the aerobic capacity and Anaerobic threshold[69] .

S N Koyal et al made study on ventilation and acid base responses during cycle ergometer and treadmill exercise. Their study reports showed that arterial lactate were higher for cycle ergometer than treadmill exercise. These differences could be produced by the greater degree of metabolic acidosis during cycle ergometer exercise[70] .

Romuald lepers et al analyzed the effects of prolonged cycling in well trained cyclists and concluded that failure of peripheral contractile mechanisms and decreased neural input to the muscles leads to reduction in leg muscular activity after prolonged cycling exercise[71] .

Sahlin and Seger study reports revealed that there is reduction in force generation capacity of quadriceps muscle after 85 min cycling exercise[72] .

Ahlquist et al study results shown that recruitment of fiber type depends upon pedaling rate and cycling with same metabolic cost at 50 rpm instead of 100 rpm resulted in recruitment of type II muscle fibers[73] .

Simon et al analyzed the plasma lactate and ventilator threshold in untrained and trained cyclists, study revealed that plasma lactate and ventilator threshold were similar[74] .

Bruno Grassi et al studied the onset of blood lactate accumulation during an incremental exercise on a ergometer cycle and reported that lactate threshold during incremental cycle exercise was significantly correlated with the onset of muscle deoxygenation [75].

Jacob et al compared the oxidative capacity of skeletal muscle and anaerobic threshold in both running and cycling, found that the VO_2 max and onset of blood lactate accumulation was higher in running than in cycling [76].

Marcinik et al and Coyle et al indicated that anaerobic threshold is influenced by muscle recruitment of lower limbs[27,77] .

Reports have revealed that differences in physiological responses between ergometer cycle and treadmill could be due to greater perception of difficulty in cycling than running [78,79]. Studies have shown that cycling performance needs greater muscular strength. Study by Millet suggested difference in VO_2 max and AT between these modes are probably due to relative adaptation of cardiac output, oxidative capacity of the exercising muscle and recruitment of muscle mass differences[22] .

AIMS AND OBJECTIVES

To study the effects of 12 weeks aerobic exercise in treadmill and ergometer cycle.

OBJECTIVES

- To study the effects of 12 weeks aerobic exercise in cardio respirative parameters like heart rate, blood pressure and maximal aerobic power.
- Metabolic parameter – blood lactate
- To compare the cardio respiratory and metabolic responses in treadmill group and ergometer cycle group.

MATERIALS AND METHODS

STUDY DESIGN:

Study is a randomized control trial for 12 weeks, comparing the physiological responses in treadmill and ergometer cycle.

Subjects were recruited from Thanjavur Medical College Hospital,in the age group of 18-40 years age group.This study was conducted in the research laboratory,Department of physiology,Thanjavur Medical College.40 female subjects with age group of 18-40 years participated in this study.

Subjects were randomized in to two groups, Group A- Treadmill group;Group B- Ergometer cycle group.

Group A consists of 20 subjects who underwent treadmill training and Group B consists of 20 subjects who underwent cycling.

Before starting our study, we obtained ethical committee approval and clearance from our college. Informed consent was obtained from all subjects who were participating in the study.

INCLUSION & EXCLUSION CRITERIA:

Healthy females with 18-40 yrs were included for this study.

Subjects with history of diabetes,hypertension,hyperlipidemia,coronary artery disease, pulmonary disease,epileptics ,on chronic medications, pregnant /

lactating individuals were excluded from the study. Athletes and individuals who were already exercising were excluded from the study.

Individuals with bony deformities/orthopedic ailments were also excluded.

APPARATUS REQUIRED:

Treadmill(cardio track whispermill Model 900XL,Browndove Health Care Ltd,Bengalore),finger pulse oximeter(Nidek Medical India,Kolkata),Ergometer cycle(Aerofit India,Hyderabad),Mercury Sphygmomanometer, weighing machine,keragen Biosstem-semi auto analyzer were used for this study.

Weight and height of the individual was measured.Systolic and diastolic blood pressures were recorded in sitting posture on the left upper limb at rest(prior to exercise) &after exercise.

Pulse oximeter used to monitor heart rate during exercise session.

Blood lactate level was measured at Biochemistry Laboratory,Thanjavur Medical College using semi automated analyzer and centrifuge machine.

TRAINING PROGRAM:

Study participants were divided into two groups,Group A –Treadmil group (n=20),Group B-Ergometer cycle Group(n=20).Before starting the study blood samples were collected for blood lactate measurement, after restraining from acute activities for at least one day, inorder to avoid the effects of acute exercise. Blood drawn from antecubital vein in anticoagulant coated container. For lactate analysis, blood samples were centrifuged and serum was separated, blood lactate levels measured using semi automated analyzer using Enzymatic method (Colorimetric LOD-PAP-Test).This procedure repeated after 12 weeks of exercise training .The subjects were asked to do exercise upto exhaustion and blood samples collected after 5 mins of post exercise[42] .

Heart rate and blood pressure (systolic &diastolic) were measured at rest. Resting heart rate was measured only after 10 mins of rest.

Before starting the exercise intervention, all the participants got familiarized with the instrument to alley their anxiety.

After orientation program, usage demo of treadmill and ergometer cycle were given.

EXERCISE SESSION;

Treadmill group:

Each exercise session was preceded by 10 mins warm up and stretching with 1.7 mph in treadmill,then increasing the speed to 4-8 mph for 20 mins duration during the initial 2 weeks.From 3rd week onwards duration increased to 30 mins. Duration & speed was increased slowly up to exhaustion level of the subject.Each session was followed by 10 mins cool down with light stretching exercises.

TIMELINE OF INTERVENTION

Duration (week)	WORK OUT TIME LINE (IN MINUTES)			FREQUENCY / WEEK
	Warm up	Aerobic Exercise	Cool down	
I – II weeks	10	20	10	5
III – XII Weeks	10	30	10	5

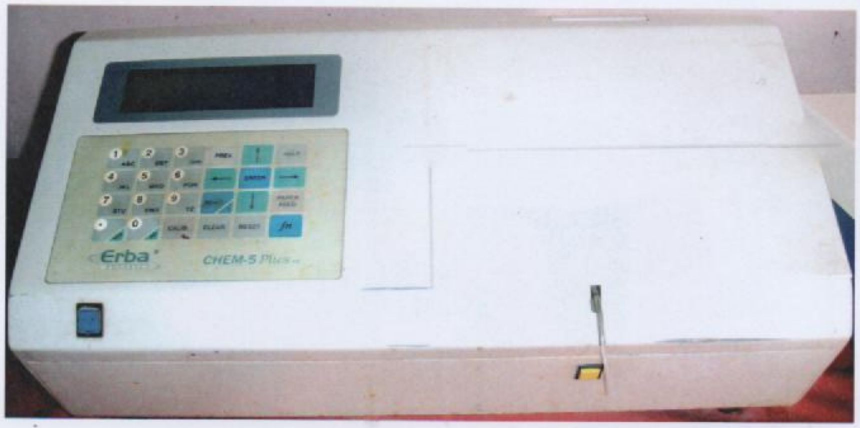
CYCLE GROUP:

To start the exercise session with warm up and pedaling speed of 30-40 revolutions per min(RPM),with resistance level in tension controller is set to one kilopond.

Pedaling speed was gradually increased to 60-70 RPM for 15 minutes with resistance being increased from 1to 4 in the tension adjuster gradually. Each session is followed by 10 minutes cool down with light stretching exercises.

Exercise session continued for 5 days in a week for 12 weeks. All subjects were informed about the adverse symptoms like chest pain, chest tightness and giddiness.

SEMI AUTO ANALYZER



ENZYME ASSAY - BLOOD LACTATE

TREADMILL EXERCISE

ERGOMETER CYCLE EXERCISE

VO_2 max was calculated using **Pederson formula**[19]

$$\frac{\text{HR max}}{\text{HR rest}} \times 15$$

Heart rate was measured continuously throughout the testing session. Resting heart rate (RHR) was identified as the lowest HR among the eight 15 sec intervals between minutes 7 and 9 of the rest. The highest heart rate during exercise session was considered as HR max [18]

During exercise, heart rate, oxygen saturation in the blood was monitored using finger pulse oximeter.

Blood pressure was recorded at rest and also immediately after exercise.

Blood lactate was measured prior to exercise session and after 12 weeks of exercise training. Under aseptic precautions, 2ml of venous blood was drawn from anticubital vein & collected in anti coagulant coated container. Blood sample was centrifuged for 3 mins and blood lactate levels were measured by using enzymatic method.

RESULTS AND ANALYSIS

This study was conducted between treadmill runners and ergometer cyclists, results were recorded for the following parameters and compared between both groups.Students paired t test was used to compare between treadmill and ergometer cycle group.

We used a level of significance of 95%(p value <0.05 as significance)

The parameters include;

I.maximum heart rate

ii.maximum oxygen consumption

iii.systolic blood pressure response

iv.diastolic blood pressure response

v.blood lactate levels.

I. MAXIMUM HEART RATE (HR max)

The mean value of maximal heart rate in treadmill group was 166.7±4.92 and the mean value of maximal heart rate in ergometer cycle group was 156±9.85.

Paired t-test result showed a statistically significant difference in MHR[P value of .000 ($p>0.05$)] . Mean HR max highest in treadmill group.

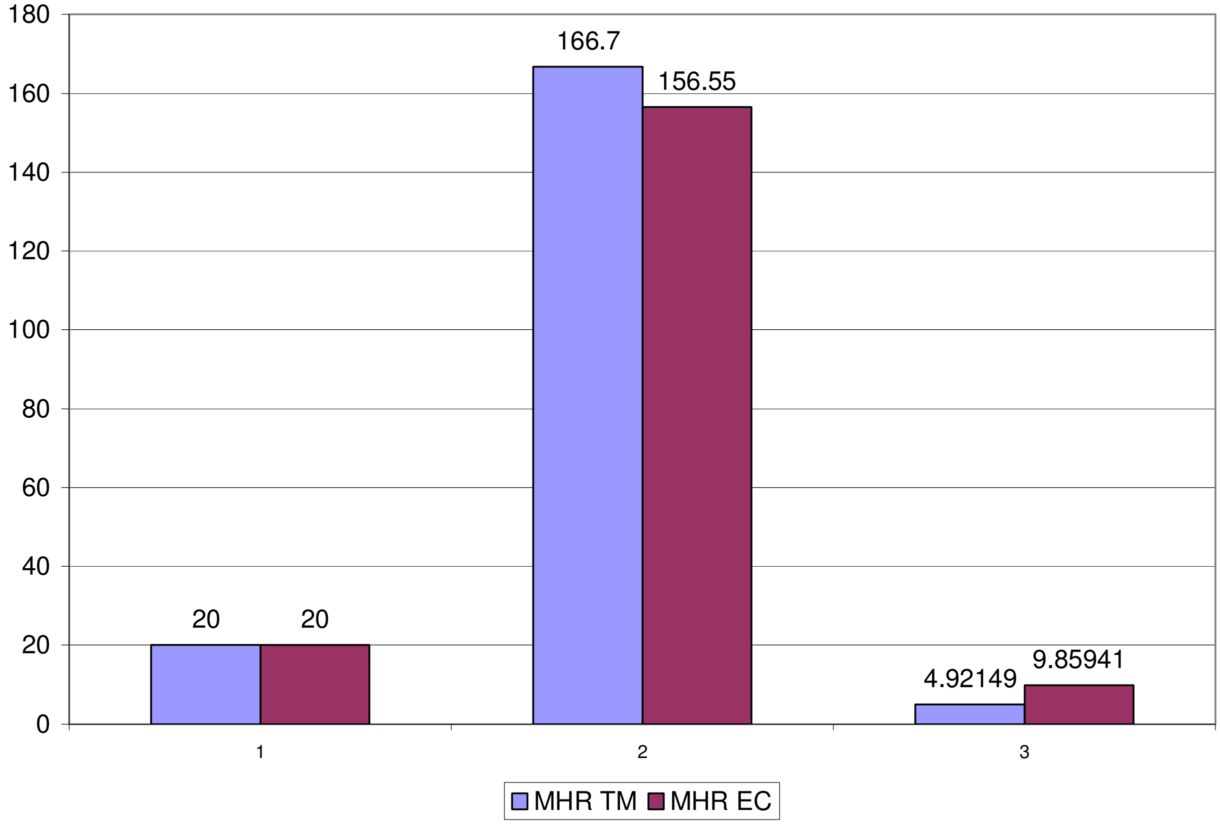
TABLE 1

Comparison of MHR between treadmill group & ergometer cycle group:

Group	**Mean**	**SD**	**'t' value**	**'p' value**
TM group	166.7	4.92	4.119	0.000
EC group	156.5	9.85		

GRAPH 1:

COMPARISON OF MHR BETWEEN TREADMILL GROUP & ERGOMETER CYCLE GROUP



II. VO_2 MAX COMPARISON

The mean value of VO_2 max in treadmill group was 30.95±2.69 and the mean value of vo_2 max in ergometer cycle group was 26.86±6.16.

There is significant increase of mean VO_2 max in treadmill group with P value of .010 ($p < 0.05$).

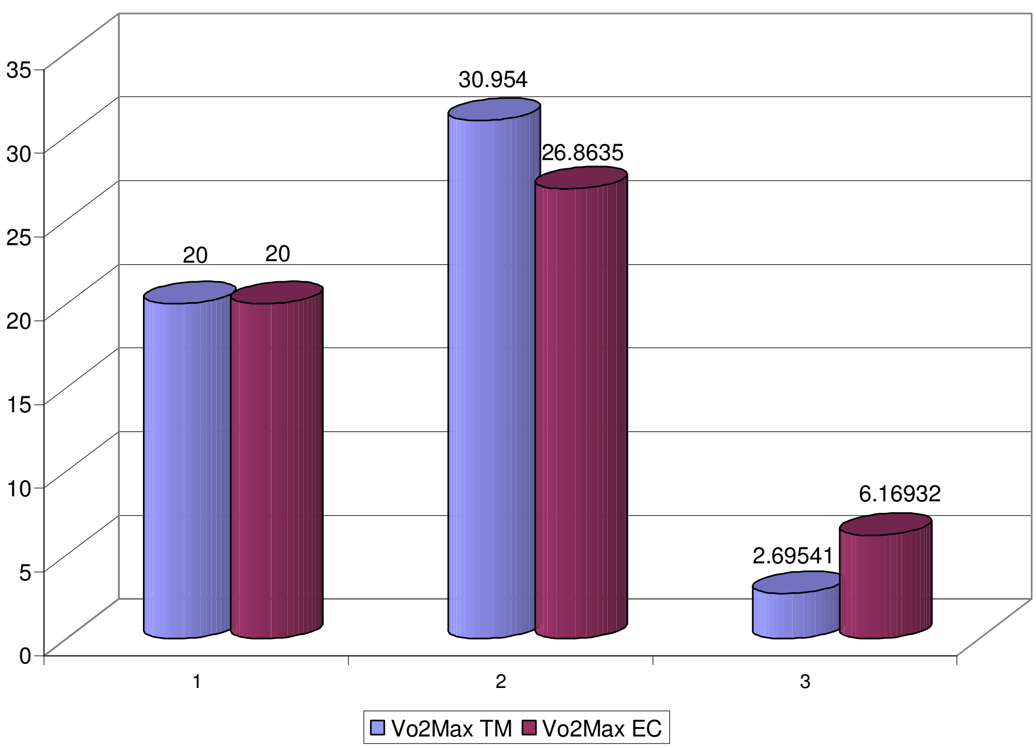
TABLE 2

Comparison of VO_2 max between treadmill group and ergometer group

Group	Mean	SD	't' value	'p' value
TM group	30.95	2.69	2.717	.010
EC group	26.86	6.16		

GRAPH 2

COMPARISON OF VO_2 MAX BETWEEN TREADMILL GROUP AND ERGOMETER GROUP



III.SYSTOLIC BLOOD PRESSURE RESPONSE (SBP)

PRE SBP:

The mean value of pre systolic blood pressure in treadmill group was 110.5±12.29mmHg and in ergometer group was 99.05±12.29 mmHg.

The results of paired‘t’ test showed statistically insignificant changes between treadmill group and ergometer group.

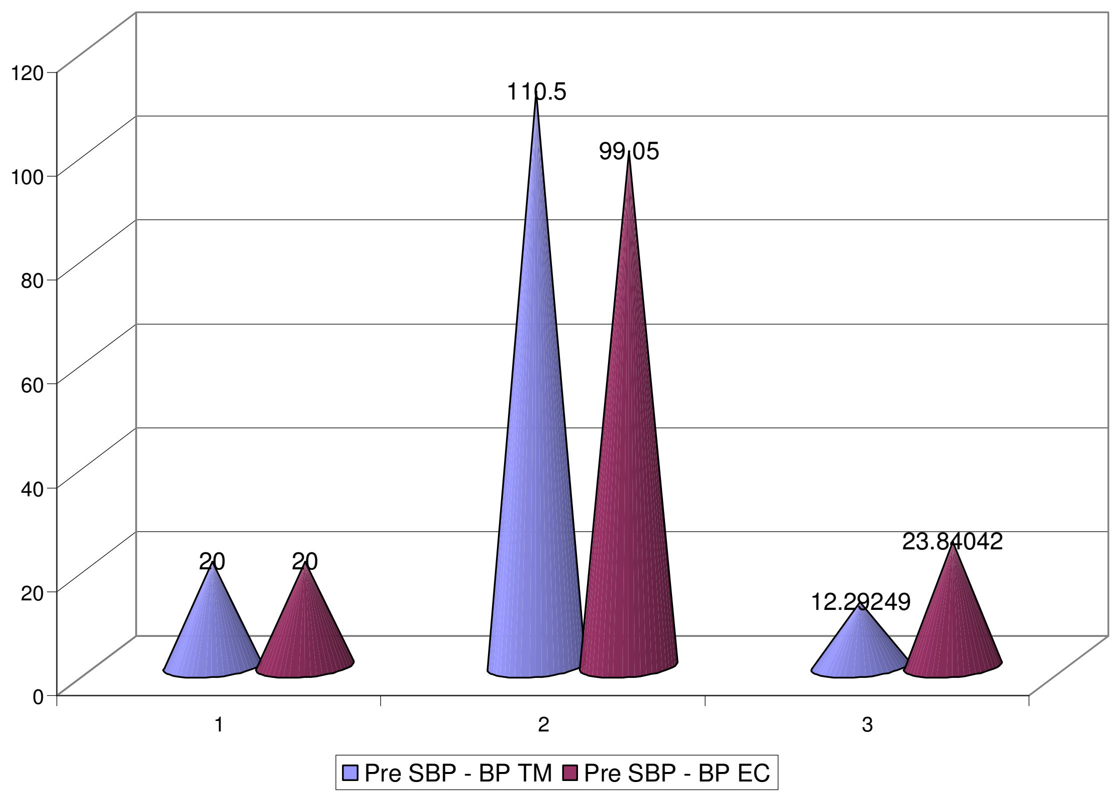
TABLE 3

Comparison of PRE-SBP between treadmill group and ergometer group

Group	Mean	SD	‘t’ value	‘p’ value
TM group	110.5	12.29	1.909	.064
EC group	99.05	23.84		

GRAPH 3

COMPARISON OF PRE-SBP BETWEEN TREADMILL GROUP & ERGOMETER GROUP



IV.DIASTOLIC BLOOD PRESSURE RESPONSE

Pre- DBP:

The mean value of pre diastolic blood pressure in treadmill group was 72.30±8.21 mmHg and the mean value of pre diastolic blood pressure in ergometer cycle group was 66.50±17.26 mmHg.

The results of paired ‘t’ test showed statistically insignificant changes [p=.183 (p>0.05)] in between treadmill group and ergometer cycle group.

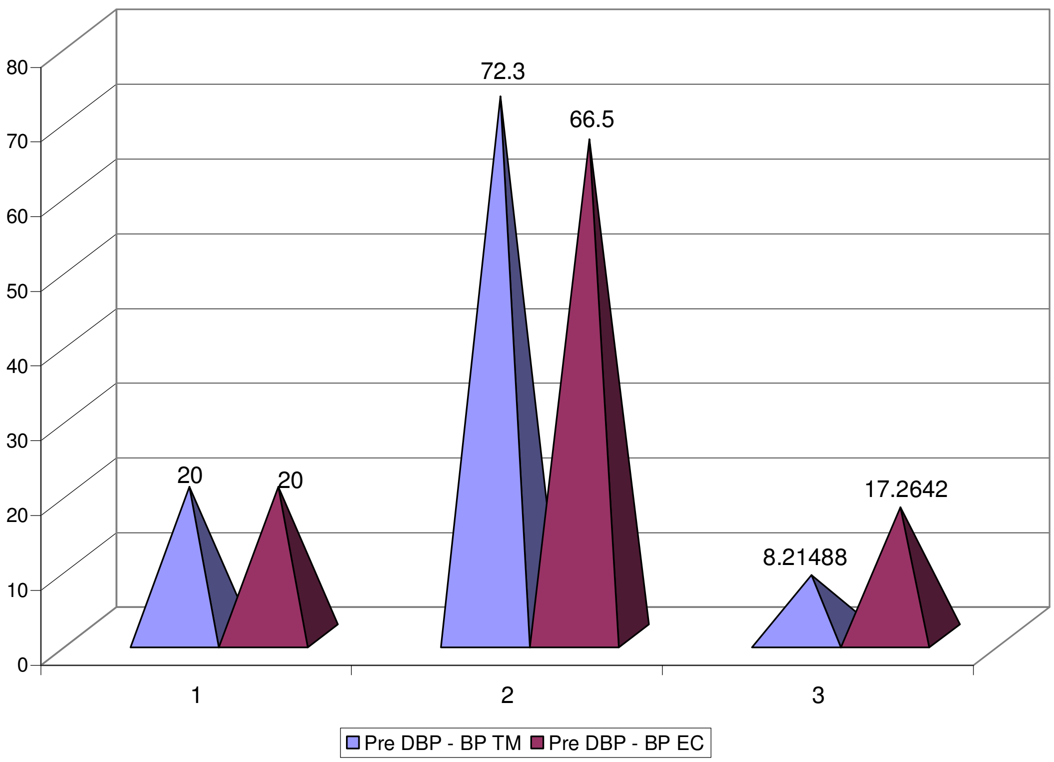
Table 4

Comparison of PRE –DBP between treadmill and ergometer group

Group	Mean	SD	‘t’ value	‘p’ value
TM group	72.30	8.21	1.35	.183
EC group	66.50	17.26		

GRAPH 4:

COMPARISON OF PRE –DBP BETWEEN TREADMILL & ERGOMETER GROUP



POST SBP COMPARISION:

The mean value of post systolic blood pressure in treadmill group was 117.2±10.28mmHg and the mean value of post systolic blood pressure in ergometer cycle group was 132.9±9.48mmHg.

The results of paired 't'test showed statistically significant changes[p=.000, p< 0.05] in post systolic blood pressure and marked elevation of post-systolic blood pressure in ergometer cycle group.

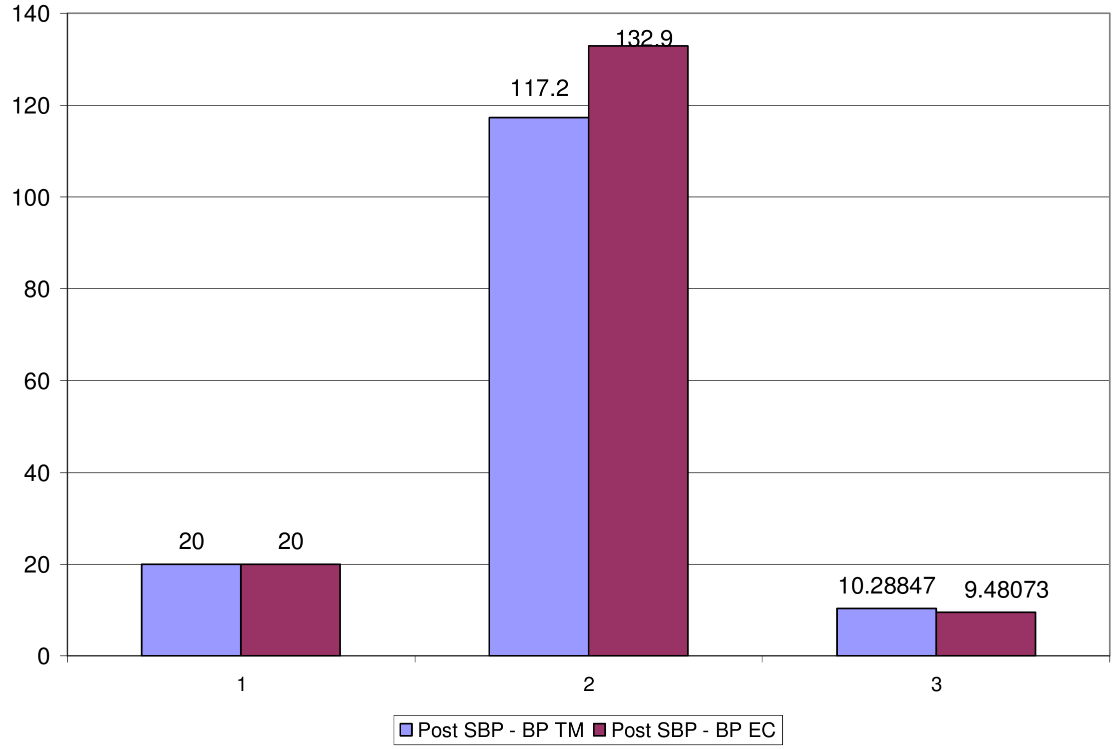
Table 5

Comparison of POST-SBP between treadmill group and ergometer group

Group	Mean	SD	't' value	'p' value
TM group	117.2	10.28	-5.09	.000
EC group	132.9	9.48		

GRAPH 5

COMPARISON OF POST-SBP BETWEEN TREADMILL GROUP AND ERGOMETER GROUP



Post- DBP:

The mean value of post diastolic blood pressure was 70.10±7.69mmHg in treadmill group and 67.00±6.75 mmHg in ergometer cycle group.

The results of paired ‘t’test showed insignificant differences in post diastolic blood pressure in between treadmill and ergometer cycle groups.

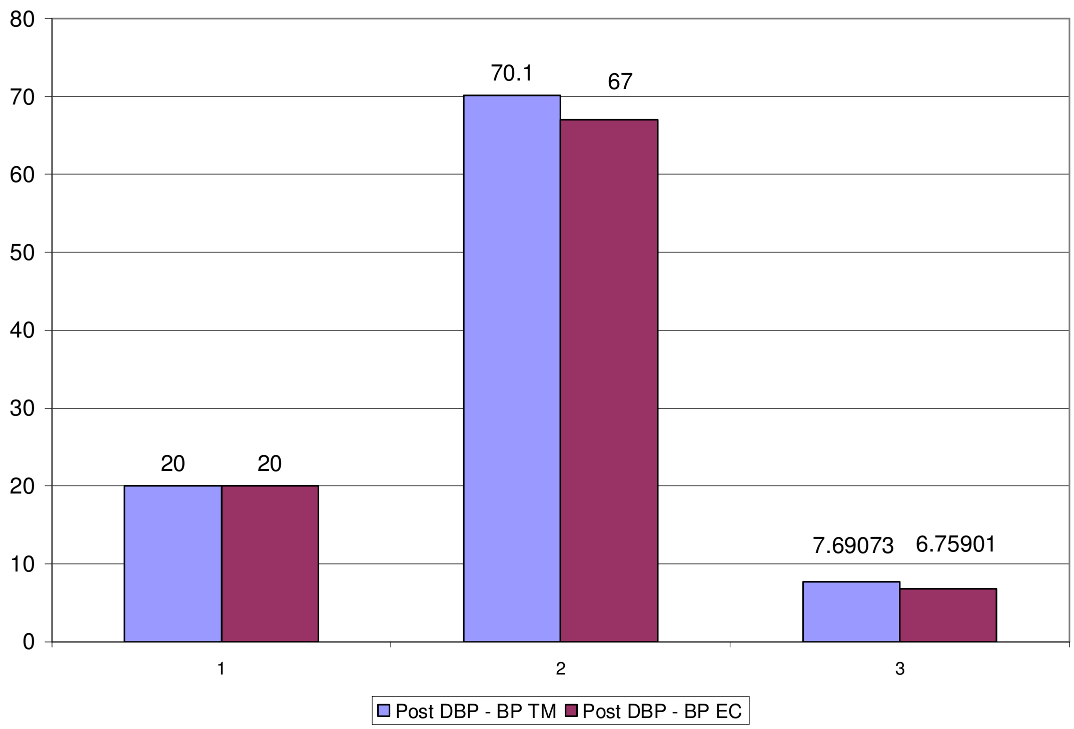
Table 6

Comparison of Post-DBP between treadmill and ergometer group

Group	Mean	SD	‘t’ value	‘p’ value
TM group	70.10	7.69	1.35	.184
EC group	67.00	6.75		

GRAPH 6

COMPARISON OF POST-DBP BETWEEN TREADMILL & ERGOMETER GROUP



V.BLOOD LACTATE

Pre –blood lactate:

The mean value of pre blood lactate was 11.04±2.66mg/dl in treadmill group and 12.28±2.28mg/dl in ergometer cycle group.

The results of paired ‘t’test showed insignificant differences [p value:0.122;p>0.05] in pre - blood lactate in between treadmill and ergometer cycle groups.

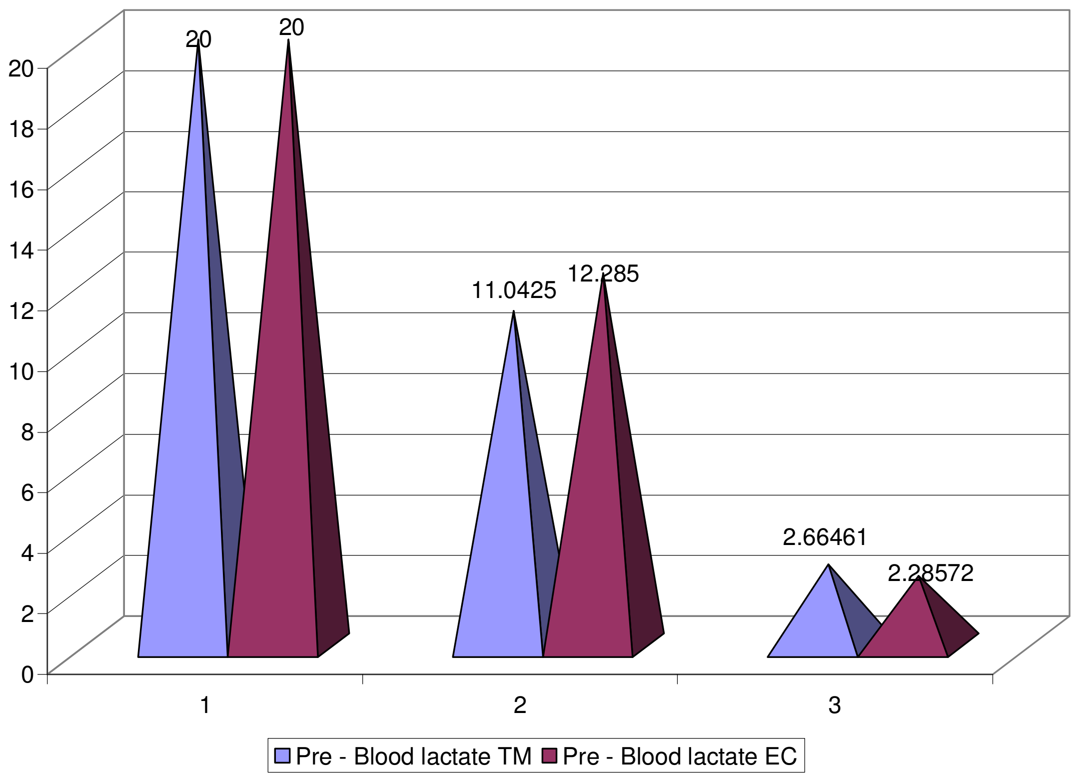
Table 7:

Comparison of Pre- blood lactate between treadmill &ergometer group

Group	Mean	SD	‘t’ value	‘p’ value
TM group	11.04	2.66	-1.583	.122
EC group	12.28	2.28		

GRAPH 7

COMPARISON OF PRE- BLOOD LACTATE BETWEEN TREADMILL &ERGOMETER GROUP



Post-blood lactate:

The mean value of post –blood lactate was 30.27±4.89mg/dl in treadmill group and 68.05±6.49mg/dl in ergometer cycle group.

The results of paired ‘t’test showed statistically significant changes[p=.000, p< 0.05] in post blood lactate in between treadmill group and ergometer cycle group. The post –blood lactate was higher in cycle ergometer group.

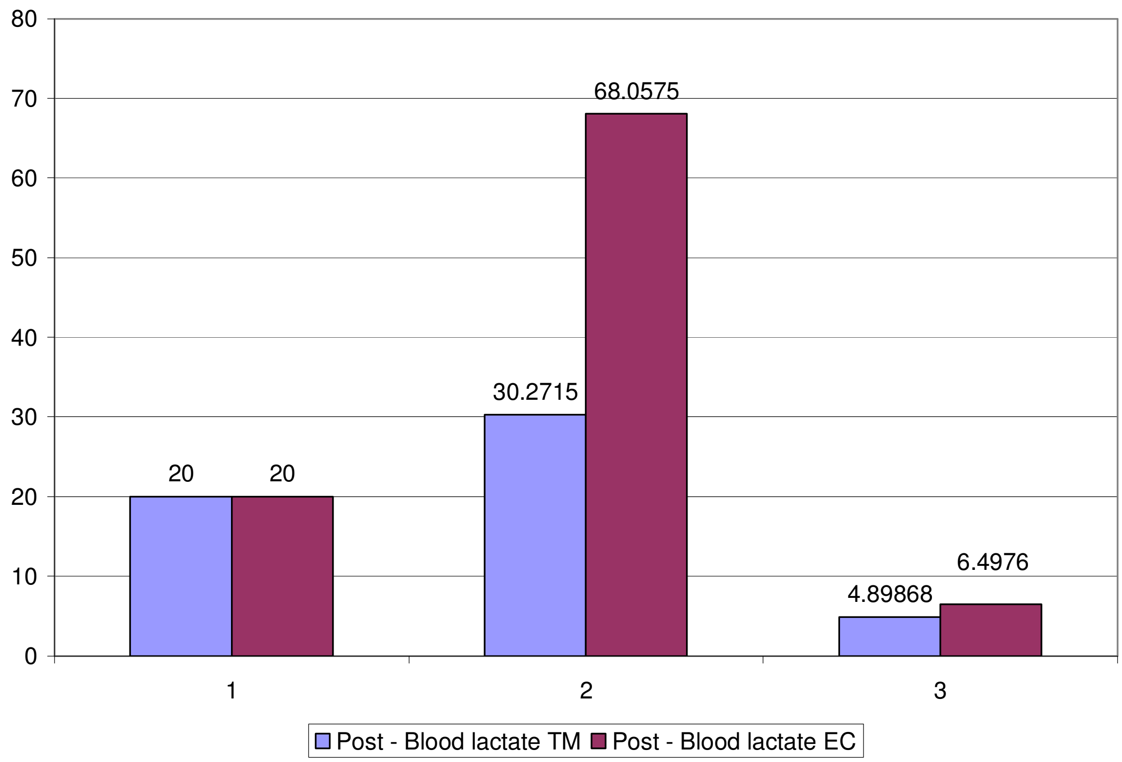
Table 8

Comparison of Post- blood lactate in treadmill and ergometer group

Group	Mean	SD	‘t’ value	‘p’ value
TM group	30.27	4.89	-20.767	.000
EC group	68.05	6.49		

GRAPH 8

COMPARISON OF POST BLOOD LACTATE IN TREADMILL & ERGOMETER GROUP



DISCUSSION

Exercise is a period of enhanced energy expenditure[6] .

There is a great interest and differences of opinion concerning the influence of regular exercise on health. Obesity is one of the major contributor for the development of cardiovascular diseases, and exercise is the logical adjunct to caloric restriction in the prevention or correction of obesity.

It is also claimed that regular exercise may prevent or delay the onset of coronary vascular disease by lowering plasma lipid and cholesterol values.

Another beneficial effect of exercise is the development of greater cardiac efficiency and provides greater contractile power to heart. By increasing vascularization of the cardiac muscle, may delay the onset of atherosclerosis.

By increasing demand of the myocardium for oxygen leads to development of collateral vascular channels in the ischemic areas and thus improves delivery of oxygen to damaged cells [29].

The exercise test have an integral places in cardiovascular medicine because of high yield of functional,diagnostic,prognostic information.

The commonest exercise test modalities are bicycle ergometer and treadmill and these tools have become far most common indoor aerobic exercise modalities.

Hence in this study, cardio respiratory and metabolic responses between these modes were compared.

CARDIORESPIRATORY RESPONSES

Treadmill and ergometer cycle are the most commonly used modalities to determine cardiorespiratory fitness of an individual.

Several studies have been done to compare Cardio respiratory responses between treadmill running and ergometer cycling.

The cardiorespiratory mechanisms differ between these modes, and shown greater VO_2 max in treadmill compared to bicycle exercise(58) .

The Aerobic capacity indicates an individual's functional status and integration of the cardio respiratory system.

It is defined as the highest attainable rate of aerobic metabolism during performance of rhythmic muscular work(6,16) .

Higher the aerobic capacity, higher is the aerobic fitness. Regular physical activity and training can improve aerobic power. Athletes have a VO_2 max twice as high as that of ordinary person of same age group.

In the present study, I have assessed and compared maximal heart rate response and maximal oxygen consumption and effect of mode on blood pressure response.

MAXIMAL HEART RATE

From hemodynamic studies performed over years, maximal heart rate has emerged as clearly the most important determinant of cardiac output during exercise.

HR max is commonly used as the indicator of maximal exercise.

In the present study, there was a significant increase in maximal heart rate in treadmill running than ergometer cycling.

Study done by Fabien et al, postulated significant differences in HRmax between treadmill and ergometer cycling ,with higher values attained by treadmill Our result confirms studies by Fabian et al(46).

Fernhall and Kohrt also showed significant differences were observed in HR max between treadmill and ergometer cycle with higher values on the treadmill running, they showed while in cycling smaller muscle mass involvement had an effect on central circulation and blood flow to leg compared with treadmill running(51,52) .

Abarentes et al also observed significant differences in maximum heart rate response and showed treadmill is the one which gives maximal heart rate attainable for a individual(43) .

Milles et al observed in 18 females in age group of 18-40 years ,their study revealed that HR max were significantly higher by 5 beats per min during treadmill running than ergometer cycling (42).

J.Faff et al found the highest HRmax during treadmill exercise in both males and females, they reported higher aerobic capacity in treadmill than exercising on ergometer cycling. Greater energy expenditure during treadmill running resulted in high HRmax values[82] .

There exists many studies to support my study result[46,80,81] .

Londeree and Moeschberger concluded that MHR obtained during treadmill running is higher than cycle ergometer[83] .

In contrast to my study result ,Schnrider and Pollack found no significant difference between cycling and running in triathletes[84] .

Studies done by Mc Ardle et al and Roecker K et al also noted same finding like ours ,such as incremental treadmill test produces higher maximal heart rate values as compared with incremental test on ergometer cycle [85,86].

Millet et al observed in triathletes ,HRmax in cycling is lowered by 6-10 beats per minute than that of treadmill running.Our study also proves the same[22] .

MAXIMAL OXYGEN CONSUMPTION

Researchers have found that treadmill and bicycle ergometer to be the most acceptable method of measuring maximal oxygen uptake[54] . Results of present study have shown that as, frequently reported by others, maximal oxygen consumption was higher on the treadmill than on the ergometer cycle.

The present study showed a $VO_{2\ max}$ difference in favor of treadmill.

VO_2 max reflects a greatest capacity for cellular utilization of oxygen[87,88].

VO_2 response is a very much valuable index which reflects the oxygen transport and muscle metabolism[87,88] .

Researchers hypothesized in concerning VO_2 max is ,if greater muscle mass used in exercise task the greater the VO_2 max[90,91] .

Glassford et al reported 8% higher VO_2max in treadmill, Chase et al observed 15% difference and Faulkner et al noticed 11% difference in favor of treadmill. [58]

Miyamura et al observed marked differences in maximum oxygen uptake by comparing maximal work on the treadmill and on the bicycle ergometer ,18% higher VO_2 max observed in treadmill. The lower VO_2 max in cycling is associated with smaller (a-v) difference and smaller cardiac output[92] .

Higher cardiac output and greater muscle mass involvement may be responsible for high VO_2 max in treadmill running [93,94].

In running there is involvement of the arms, legs and other muscles of the body thereby eliciting higher aerobic capacity, but for cycling while seated, arms were stablished, there forth performing little or no work. Cardiac output was lower in cycling compared with running, due to sustained muscle contraction, impairment of venous return & lower stroke volume.

Walla Mohamed Elsais et al in their comparison of maximal oxygen consumption in different mode of exercise ,described higher VO_2 max during treadmill running (similar to my study).The muscle contraction regime differ between running and cycling., In cycling mechanical efficiency is lowered due to concentric work pattern. But running relies on stretch stretching movements attribute to higher efficiency. In standing, during inspiration lung volume increases and during expiration, greater expiratory muscle contraction and also less air flow obstruction in the airways are contribute to VO_2 max differences in between two modes [55].

In contrast with our study results, Bilat at al reported higher maximal oxygen consumption during cycling than running. The difference may be due to different protocols and small sampling test[95].

Phillips et al noticed the effects of endurance training, and reported increase in size and number of mitochondria and increase in oxidative enzyme concentration after training. This might be the cause for an acceleration of VO_2 Kinetics on training[96].

Hasia et al also observed high VO_2 max in treadmill ,they explained this with large muscle mass involvement in running[49].

Faulker et al found that lower VO_2 max was associated with lower stroke volume. In cycling cardiac output is low compared to running, which may be due to limited venous return contributes to reduced cardiac filling, there by influencing oxygen consumption. Peripheral blood flow to lower extremities during cycling is different[93] .

Muscle pump facilitates venous return and perfusion of skeletal muscle .The muscle pump efficiency which augment local blood flow is greatly dependent upon type of activity .Studies have reported that running evokes greater muscle pump efficiency, because in erect posture efficiency is more.Strech shortening contraction which happens during running induces pro inflammatory response that itself increases blood flow to the muscle[22].

Kasch et al observed higher VO_2 max in uphill running can be due t longer duration o test and fast running rate, these factors produces greater muscle demand for oxygen[97].

In cycling VO_2 max was limited by adaptation of heart capacity and compared with running, cycling induces great stress on respiratory mechanisms. The possible explanations are 1. greater metabolic acidosis could be origin of greater pulmonary ventilation on cycling.2.In cycling ,greater strain on leg muscles causes an increase in neurostimuli from leg proprioceptors. In treadmill running, the strain is uniformly distributed over active muscles and the action of neural impulse is less active[58].

BLOOD PRESSURE RESPONSE

Normal BP response to exercise is characterized by a progressive increase in systolic pressure, decrease or no change in diastolic pressure.

Systolic pressure increases in both treadmill or ergo meter cycle on increasing workloads. Diastolic pressure usually remains same.

Rising diastolic pressure can be associated with coronary artery disease and this is a marker for labile hypertension.

Our study result showed significant increase of systolic blood pressure in cyclists compared to runners.

Young Joo Kim et al reported treadmill test as the most accurate measure of HR max andVO_2max.Treadmill has the higher sensitivity in detection of myocardial ischemia. Blood pressure response at a maximal exercise is stronger in ergo meter cycle, than in treadmill, leads to increase in rate pressure product. Hence, it is possible that cycling may be a burden to cardiovascular system(63).

In athletes studies have shown an increased systolic BP response in ergometer cycle than treadmill .In cycle athletes systolic BP reaches to 200mmhg in ergometer cycling(98).

Fagard analyzed 947 athletes and reported cycling increases the thickness of myocardial wall and inside diameter of the left ventricle(99).

REED reported Systolic blood pressures at 40% and 60% reserve as higher in cycle ergometry than treadmill and SBP at the maximum workload was higher in cycle ergometry than treadmill. This report is similar to my study result(64).

Franklin et al & Blomqvist et al reported that, there are many factors that account for this systolic blood pressure higher during cycling. Cycling as opposed to treadmill running associated with reduced mechanical efficiency. smaller muscle mass involved in cycling offers greater resistance to blood flow [100,101] .

Bunker et al explained higher vasoconstrictive responses produced by non exercising muscle contributes to greater SBP in cycling[102].

Unlike treadmill running, in cycling on increasing intensity causes greater upper body isometric muscle contraction and higher intramuscular tension on lower body[57].

Blood pressure response in treadmill and cycling may be due to mechanical factors interacting with increased blood volume and left ventricular overload associated with cycling, since it offers greater resistance to blood flow

Raised systolic blood pressure in cycle ergometry can increase the myocardial burden of patients with ischemic heart disease[64]..

BLOOD LACTATE :

The Anaerobic Threshold has great application in evaluation of physical fitness in normal individuals and in patients with cardiovascular insufficiency[33].

Its application in exercise testing gives information regarding cardiovascular function in disease and health.

In my study Blood lactate levels significantly increased in ergometer cycle group. Here I have enclosed few studies which correlate with my study result.

Both VO_2 max and anaerobic threshold may indicate a person's physiological ability to tolerate major surgery[36].

Studies have proved that the elevation of lactate during exercise is related to work intensity and that increase in normal individuals above critical work loads. If the individual is more physical fit, the lower lactate level at a given work rate[103].

Patients with cardiovascular functional abnormality have lower lactate threshold than normal subjects.

Studies have revealed that endurance training increases anaerobic threshold during incremental exercise as because skeletal muscle has enormous capacity of adaptation[104].

Cycling and running activity is performed by contraction of lower limb muscles. The main muscle group involved in running and cycling are plantar flexors and quadriceps respectively[105].

Researchers suggested that the difference in AT for running and cycling are expression of differences in recruitment of muscle during exercise[22].

Millet et al proposed that higher lactate concentration after cycling than running due to difference in oxidative and glycolytic process[22].

Scott et al also proposed the difference in energy transfer,glucolytic component was higher in cycling than running[53].

Coyle et al compared AT in in trained cyclists, reported that cycling skill and muscle recruitment patterns are important factor in determination of anaerobic threshold in cycling[77].

Therefore specific training adaptations and involvement of different muscle groups influences AT.

Jacob at al have done study on comparison of oxidative capacity of skeletal muscle and anaerobic threshold in both running and cycling, found that the onset of blood lactate accumulation(OBLA) was higher in running than cycling[76] .

Hsia et al described that muscle mass used is smaller in cycling than in running, leaded to lower anaerobic threshold in cycling[49] .

Miles et al analyzed metabolic responses of females to treadmill and cycling exercise and noticed higher lactate production in ergo meter cycle exercise. Plasma bicarbonate and pH were significantly lower in exercise on cycle ergometer exercise. Disturbance of acid base balance greater during cycling. The elevation of lactate may be due to usage of smaller muscle mass or implementation of greater load on the subject. The higher lactate during cycling hold the possibility of anaerobic metabolism during cycle test[42] .

Wiswell et al analyzed anaerobic threshold in endurance athletes and pointed out that runners reached higher anaerobic threshold than cyclists, concluded that the AT was influenced by sports practiced[106] .

Medelli et al stated that differences observed between these modes could be due to difference in muscle mass involvement and distribution of motor units in each mode. They concluded anaerobic threshold strongly related to exercise mode[58].

Walaa et al noticed lower respiratory exchange ratio and tidal volume on treadmill, this probably refer to greater metabolic acidosis during ergometer cycling. Reason for greater metabolic acidosis could be due to smaller muscle mass involvement[55] .

Rice et al reported that blood lactate accumulation increases with increasing intensity of exercise in cycling, also have contributed to metabolic acidosis on ergometer cycling[107].

CONCLUSION

This study was designed to compare cardiorespiratory and metabolic responses between treadmill running and ergometer cycling.

The results of the present study indicated that treadmill running elicited higher cardio respiratory responses than bicycle ergometer.HRmax and VO_2 max can accurately measured by treadmill, therefore the sensitivity in detecting myocardial ischemia is higher in treadmill than ergometer cycling. Blood pressure response is stronger in cycling than running.

The clinical importance of these findings is that bicycle constitutes a greater stress on the cardiovascular system for any given oxygen uptake than treadmill exercise. On the other hand, treadmill exercise produces less hemodynamic stress on cardiovascular system. Thus treadmill can be recommended for development of cardiovascular/respiratory fitness.

In essence, the results of this study showed significant differences in cardiorespiratory and metabolic responses in treadmill running and ergometer cycling.

LIMITATION

Limitations of this study are:

During exercise, we were not able to record blood pressure because of limitation of automated blood pressure monitor.

The study size was of modest because of difficulty in recruiting female subjects with normal BMI.

REFERENCES

1.Lakka TA,Laeksonen De,Lakka Hm,Mannikon,Niskanen LK,Ravara R,Solonen JT, Medicine and science in sports and exercise .2003,35(8)1279-1286.

2.Sarika Chaudhary,Manpreet Kang,Jaspal singh sandhu.The effects of Aerobic versus Resistance training on cardiovascular fitness in obese sedendary females.Asian J.sports med 2010.Dec;1(4)177-184.

3. American college os sports medicine ACSM's Guidelines for exercise testing and prescription 8th edition.

4.Wilmore,j.Knuttgen,H.2003.Aerobic Exercise and endurance Improving Fitness for Health Benefits.The Physician and Sports medicine,31(5).45

5.Exercise and Sportcardiology,PaulD.Thompson,McGRAW-HILL INTERNATIONAL EDITION .PP-75-84.

6.Walter F.Boron.Emile L,Bouloaeo,Medical physiology Acellular and molecular approach,second medicine,Saunders company.

7. Victor F. Froelicher,Jonathan N.Myers,Exercise and the Heart .4th edition, W, B. Saunders company,

8.Cengiz akalan,Robert A,Robersgs,Len Kravitz.Prediction of VO2max from an individualized submaximal cycle ergometer protocol

9. Haruthi ITOH,Ryuichi Ajisaka,Akira koike,Shigeru Makita.Heart rate and blood pressure response to ramp exercise and exercise capacity in relation to age ,gender,and mode of exercise in a healthy population. Journal of cardiology 61(2013)71-78.

10.S Grant,K Corbett,AM Amjad,J Wilson and T Aitchison Acomparison of methods of predicting maximum oxygen uptake .Br.Jour .Sports Med,Vol.29,No.3,pp.147-152,1995.

11.William Mc Ardle D,Katch FI,Katch VL.Exrcise Physiology:Nutrition,Energy and Human Performance.7th ed.Lippincott Williams &Wilkims;Baltimore.

12. Clarke Harrison, Basic understanding of physical fitness.Physical activity and fitness research digest series 3,No .9,march2000

13.Understanding Your Health,Wayne A.Payne ,Dale B.Hahn.Times mirror/mosby college publishing.pp 67-83.

14.Text book of medical physiology.Pal GK.second edition.Ahuja.

15.Indu Khurana.Textbook of Medical Physiology.First edition .Elsevier.

16.Ak jain.Test book of physiology.Fifth Edition,Avichal publishing company.

17. William J Kraemer,Steven J .Fleck,Michael R.Deschenes, Exercise physiology; Integrating Theory and Application :Wolters Kluwer/Lippencott Williams &Wilkins.

18.Jeanie M.Haller,Patrica C. Fehling,David A,Barr,Thomas W,Storer,Chistopher B,Cooper &Denise L.Smith.Use of the HR index to predict maximal oxygen uptake during different exercise protocols. Physiological Reports,2013/vol.1/Iss.5.

19.Niels Uth.Henrik Sorensen.Kristian Overgaard .Preben K. Pedersen.Estimation of VO2max from the ratio between HR max and HRrest-the Heart Rate Ratio Method, Eur J Appl physiol(2004)91;111-115.

20.Hall JE,Guyton AC.Textbook of Medical physiology.12th ed.Elsevier Saunders.

21. Bruce M .Koeppen,Bruce A.Stanton.Berne &Levy physiology,sixth edition, Mosby Elsevier.PP-405-408.

22.Gregoire P.Millet,V.E.Vleck and D.J.Bentley.Physiological Differences between Cycling and Running.Lessons from Triathletes.Sports Med 2009;39(3):179-206.

23.Boussana A,Matecki S,Galy o,O, et al.The effects of exercise modality on respiratory muscle performance in triathletes.Med Sci Sports Exerc 2001 Dec;33(12);2036-43

24.Hermensen L,Ekblom B,Saltin B. Cardiac output during submaximal and maximal treadmill and bicycle exercise.JAppl Physiol 1970 Jul;29(1);82-6

25.Rowland TW.The circulatory response to exercise ;role of the peripheral pump.Int J Sports Med 2001 Nov;22(8);558-65.

26.Millet GY,Lepers R.Alterations of neuromuscular function after prolonged running,cyling and skiing exercises.Sports Med 2004;34(2)105-16.

27.Marcinik EJ,Potts J,Schlabach G et al.Effects of strength training o lactate threshold and endurance performance.Med Sci Sports Exerc 1991 Jun;23(6)739-43.

28.Shoron A,Plowman,Denise L.Smith,Exercise physionogy for Health,Fitness&Perfection, Second edition.Wolter Kluwer.Philadelphia.

29.A.T.Miller,Energy Metabolism,F.A.Davis company.Philadelphia.pp 5-18.

30.Krista Svedahl and Brian R.MacIntosh Anaerobic Threshold ;The concept and Methods of Measurement.Can J Appl.Physiol.28(2):299-323.

31. Brooks G.(1985).Anarobic threshold;review of the concept and directions for future research.Medicine and Science in sports and Exercise,17,22-31.

32.Sports and exercise Physiology testing Guidelines.The British Association of Sport and Exercise Sciences Guide.Vol 2-Exercise and clinical testing.

33.Wasserman, K,Whip,B.,Koyal,S.,Beaver W.(1973). Anaerobic threshold and respiratory gas exchange during exercise.Journal of Applied Physiology,35,236-243.

34.Braunwald Zipes Libry.A textbook of cardiovascular medicine.6th edition. W.B. Saunders company.

35.David C.Poole and Glenn A.Gaesser .Response of ventilator and lactate thresholds to continuous and interval training.J.Appl.Physiol.58(4);1115-1121,1985.

36.J.L.Orr,P.Williamson,W.Anderson,R.Ross,S.McCafferty and P.Fettes. Cardio pulmanary exercise testing;arm crank Vs cycle ergometry.Anesthesia 2013,68,497-501.

37.Kravitz L,Robergs RA,Heyward VH,Wagner DR,Powers K.Exercise mode and gender comparisons of energy expenditure at self-selected intensities.Med Sci Sports Exerc1997;29;1020-1035.

38 Klein J,CheoS,Berman DS,Rozanski A.Pathophysiologic factors governing the variability of ischemis responses to treadmill and bicycle exercise.Am Heart J 1994;128(5)948-55.

39.Bouckaert J,Vrijens J,Pannier JL.Effects of specific test procedures on plasma lactate concentration and peak oxygen uptake in endurance athletes.J Sports Med Phys Fitness 1990 Mar;30(1);13-8.

40.Boileau RA,Bonen A,Heyward V.H and Massy ,B.H(1977)M aximal aerobic capacity on the treadmill & Bicycle ergometer of boys 11-14 yrs of age .Journal of sports medicine & physical fitness 17,153-162.

41.Hambrecht RP,Schuler GC,Muth T,Greater diagnostic sensitivity of treadmill versus cycle exercise trsting of asymptomatic men with coronary artery disease. Am J Cardiol 1992;70(2)141-6.

42.Miles,Daniel S,Jerry B,Critz and Ronald G.Knowlton. Cardiovascular ,metabolic and ventilator responses of women to equivalent cycle ergometer and treadmill exercise.Medicine and science in sports and exercise ,vol.12,No.1,pp,14-19.1980.

43.C.Abrantes ,J.Sampaio,V.M.Reis,N.Sousa,J.A.Duarte.Physiological responses to treadmill and cycle exercise.Int J Sports Med 2012;33:26-30.

44.Kenneth R.Turley and Jack H. Wilmore .Submaximal cardiovascular responses to exercise in children;Treadmill Versus Cycle ergometer.

45.Martinez ML,Ibanez Santos J, Grijalba A,Santesteban MD,Gorostiaga EM.Phyiological comparison of roller skating,treadmill running and ergometer cycling,Int J Sports Med .1993 Feb;14(2):72-7.

46.Fabien A. Basset ,Marcel R.Boulay.Specificity of treadmill and cycle ergometer tests in triathletes,runners and cyclists.Eur J Appl PHYSIOL(2000)81:214-221.

47.Moreira –Da-Costa,Russo AK,Picarro IC,Barros Neto TL,Silva AC,Leite-De-Barros-Neto JK (1984).Maximal oxygen uptake during exercise using trained or untrained muscles.Braz J Med Biol Res 17:197-202.

48.Ravikiran Kissan,Swapnali Ravikiran Kissan ,Anitha &Chandrakala SP.Treadmill and bicycle exercise;Cardiovascular response comparison.Global Journal of Medical Research.Vol 12 Iss5 Version 1.0 June 2012.

49. D.Hsia,R.Casaburi,A.Pradhan,E.Torres and J.Porszasz.Physiological responses to lenear treadmill and cycle ergometer exercise in copd.Eur Respir J 2009;34:605-605

50. J,L.Pannier.,J.Vrijens,and C.Van Cauter. Cardiorespiratory Response to Treadmill and Bicycle Exercise in Runners. Eur J Appl Physiol 43,243-251 (1980)

51.Kohrt WM,Morgan DW,Bates B,et al .Physiological responses to triathletes to maximal swimming,cycling,and running.Med Sci Sports Exerc1987 Feb;19(1)51-5

52.Fernhall B,Kohrt W.The effect of training specificity on maximal and submaximal physiological responses to treadmill and cycle ergometry.J Sports Med Phys Fitness 1990 sep;30(3):268-75.

53.Scott CB,Littlefield ND,Chason JD,et al.Differences in oxygen uptakebut equivalent energy expenditure between a brief bout of cycling and running.Nutr Metab(Lond)2006;3:1.

54. G..A.McKay and E.W.Banister. A Comparision of maximum oxygen uptake determination by bicycle ergometry at various pedaling frequencies and by treadmill running at various speeds. Europ.J.appl.Physiol.35,191-200(1976)

55. Walaa Mohamed Elsais and Walaa Sayed Mohammad.Effect of different exercise modes on cardiovascular responses in male runners.World Jour of Sports Sciences 5(3);191-196,2011

56.Montgomery,D.L.Physiology of ice hockey.Sports Med 5;99-126,1988.

57.Helan carter,Andrew m.Jones,Thomas J.Barstow,Mark Burnley ,craig A.williams and Jonathan H.Doust-j appl physiol 89;899-907,2000.

58. Medelli J,Maingourd Y,Bouferrache B,Bach V,Frevile M,Libert JP. Maximal oxygen uptake and aerobic –anaerobic transition on treadmill and bicycle in triathletes. Jpn J Physiol 1993;43(3)347-60.

59.Smith EW,Skelton MS,Kremer DE,Pascoe DD,Gladden LB,Lactate distribution in the blood during progressive exercise. Med.Sci.Sports Exerc 1997/may 29(5):654-60.

60.Astrand PO & Rhyming I.A normogram for calculation of aerobic capacity/physical fitness from pulse rate during submaximal work J Appl P hysiol 1954;7:218-221.

61. Wicks,J.R.,N.B.Oldridge ,L.K.Nielsen and C.E.Vickers.2011.HRindex-a simple method for the prediction of oxygen uptake.Med.Sci.Sports Exerc.43;2005-2012.

62. Collins MA,Cureton KJ,Hill DW,Ray CA.Relationship of heart rate to oxygen uptake during weight lifting exercise.Med Sci Sports Exerc. 1991 May;23(5)636-40.

63.Young Joo Kim,Heaja Chun ,Chul –Hyun Kim, Exaggerated response of systolic blood pressure to cycle ergometer .Ann Rehabil Med 2013;37(3)364-372.

64.Justy Reed,Blood pressure responses of African American women during cycle and treadmill exercise.Ethnicity Disease 2007,Volume 17,59-64.

65. C.C.Christensen,M.S.Ryg,A.Edvardsen,O.H.Skjonsberg.Effect of exercise mode on oxygen patake and blood gases in copd patients.Respiratory medicine (2004)98,656-660.----X1

66.S.Kurl,MD;Laukkanen,MD;Rauramaa,MD,T.A.Lakka,MM,J.Sivenieus,MD;J.T.Salonen,MD.systolic blood pressure response response to exercise stress test and risk of stroke .Journal of American heart association .2001;32;2036-2041.

67. Moghiseh M,Habibi E,Aramesh N,Hasanzadeh A ,Khorvash MK, Poorrahmatian AH(2013) .The association between VO2 max and heart rate of casting industry workers.JOHE,Winter –spring 2013;2(1-2)

68. Arts FJ,Kuipers H. The relation between power output,oxygen uptake and heart rate in male athletes.Int joupnal of sports medicine 1994;15(5);28-31.

69. Esposito F,Impellizzeri FM,Margonato V ,Vanni R ,Pizzini G,Veicsteinas A. Validity of heart rate as an indicator of aerobic demand during soccer activities in amateur soccer players.Eur J Appl Physiol 2004; 93(1-2);167-72.

70. SN Koyal,B J Whipp, D Huntsman G A Bray ,Ventilatory responses to the metabolic acidosis of treadmill and cycle ergometry.Journal of applied physiology (Impact F actor:3.43).07?1976;40(6);864-7.

71 Romuald Lepers,Christophe Hausswirth,Nicola Maffiuletti,Jeanick Brisswalter and Jacques Van Hoecke. Evidence of neuromuscular fatigue after prolonged cycling exercise. Med. Sci Sports Exerc ,2000,Vol,32,No.11,1880-1886

72.Sahlin,K, and J.Y.Seger.Effects of prolonged exercise on the contractile properties of human quadriceps muscle.Eur J Appl.Physiol71;180-186,1995.

73.Ahlquist ,L.E,D.R.Basset,R.Sufit,F.J.Nagle and D.P. Thomas. The effect of pedaling frequency on glycogen depletion rates in type I and II quadriceps muscle fibers during submaximal cycling exercise.Eur.J.Appl.Physiol.65;360-364,1992.

74.Simon,J.Y oung,J.,Blood,D,Segal,K,Case,R.,Gutin,B.(1986).Plasma Lactate and ventilation thresholds in trained and untrained cyclists.journal of Appllied Physiology,60,777-781.

75.Bruno Grassi,Valentina Quaresima,Claudio Marconi,Marco Ferrari,and Paolo cerretelli. Blood lactate accumulation and muscle deoxygenation during incremental exercise.J Appl .physiol.87(1);348-355,1999.

76.Jacobs I,Sjodin B.Relationship of ergometer-specific VO2max and muscle enzymes to blood lactate during submaximal exercise.Br J Sports Med 1985 Jun;19(2);77-80.

77.Coyle EF,Feltner ME,Kautz SA,et al.Physiological and biomechanical factors associated with elite endurance cyling performance.Med Sci Sports Exerc 1991 Jan;23(1):93-107.

78.Hassmen P,Perceptual and physiological responses to cycling and running in groups of trained and untrained subjects.Eur J Appl Physiol Occup PP hysiol 1990;60(6):445-51

79.Borg G,Van den Burg M,Hassmen P.Relationships between perceived exertion ,HR and HLa in cycling ,running and walking.Scand J Sports Sci 1987;9:69-77.

80.BoulayMR,Simoneau JA,Lortie G,Bouchard C(1997)Monitoring high-intencity endurance exercise with heart rate and thresholds.Med Sci Sports Exerc 29;125-132.

81.Hill DW,Hallcomb JN,Stevens EC.Oxygen uptake kinetics during severe intensity running and cyling.Eur J Appl Physiol 2003:89:612-618.

82.J.Faff,D.Sitkowski,M.Ladyga,A.Klusiewicz,L.Borkowski,J.Starczewska-Czapowska.Biology of sport,VOL.24 NO2,2007l and bicycle ergometer exercise.International Journal of Sports Medicine 3;43-46.

83.Londeree B.R,M.L.Moeschberger(1984)Influence of age and other factors on maximal heart rate.J Cardiac .Rehab.4:44-49.

84.Schneider DA,Pollack J.Ventilatory threshold and maximal oxygen uptake during cyling and running in female triathletes.Int Sports Med 1991 Aug ;12(4):379-83.

85.McArdle WD,Magel JR.Physical work capacity and maximum oxygen uptake in treadmill and bicycle exercise.Med Sci Sports 1970 Fall;2(3);118-23.

86.Roecker K,Striegel H,Dickhuuth HH.Heart –rate recommendations ;transfer between running and cycling exercise .Int J Sports Med 2003 Apr ;24(3):173-8.

87.Astrand PO,Saltin B.Maximal oxygen uptake and heart rate in various types of muscular activity.J Appl Physiol 1961 Nov;16:977-81.

88.Saltin B,Nazar K,Costill DL,et al. The nature of the training response;peripheral and central adaptations of one legged exercise.Acta Physiol Scand 1976 Mar;96(3);289-305.

89.F.Caputo,M.T.Mello and B.S.Denadai.Oxygen uptake kinetics and time to exhaustion in cycling and running; a comparison between trained and untrained subjects. Archives of Physiology and Biochemistry.2003,Vol.111,No.5,pp 461-466.

90.Gleser MA,Hortsman DH,Mello RP.The effect on VO2max of adding arm work to maximal leg work.Med Sci Sports 1974 Summer;6(2);104-7.

91.Secher NH,Ruberg- Larsen N,Binkhorst RA,et al. Maximal oxygen uptake during arm cranking and combined arm plus leg exercise.

92.Miyamura M,Kitamura K,Yamada A, and Matsui ,M.1978.Cardiorespiratory reponses to maximal treadmill and bicycle exercise in trained and untrained subjects.Sports Med and Physical Fitness,18,25-32.

93.Faulkner JA,Roberts DE,Elk RL,and Conway J;Cardiovascular responses to submaximum and maximum effort cycling and running.J Appl Physiol 30;457-461,1971.

94.Hermansen and Saltin B:Oxygen uptake during maximal treadmill and bicycle exercise. J Appl Physiol 26;31-37,1969.

95. Bilat ,V.L.,Richard,V.M.Binsse,J.P.Koralsztein and P.Haouzi,1998.The VO2slow component for severe exercise depends on type of exercise and is not correlated with time to fatigue.J.Appl.Physiol.,85:2118-2124.

96. Phillips SM,Green HJ,Macdonald mj,Hughson RL.Progressive effect of endurance training on VO2 kinetics at the onset of submaximal exercise. J APPL Physiol 79;1914-1920.

97.Kasch FW,Wallace JP,Huhn RR,Krogh LA,and Hurl PM;VO2max during horizontal and inclined treadmill running.J Appl Physiol 40;982-983,1976.

98.MacDougall JD,Tuxen D,Sale DG,Morez JR,Sutton JR,Arterial blood pressure response to heavy resistance exercise.J Appl Physiol 1985;58:785-90.

99.Fagard R.Athlete’s heart.Circulation 2001;103;E28-9.

100.Franklin BA.Exercise testing,training and arm ergometry,Sports Med.1985;2:100-119.

101.Blomquist CG,Lewis SF, Taylor WF,Graham RM.Similarity of haemodynamic responses to static and dynamic exercise of small muscle groups,Circ Res 1981;148:187-192.

102.Bunker CH,Ukoli FA,Nwankwo MU et al.Factors associated withhypertensionin Nigerian civil servants.Prev Med. 1993;21;710-722.

103.Ekblom B.,P.O.Astrand ,B.Saltin,j.Stenberg and B.Wallstrom.Effect of training on circulatory response to exercise.J Appl.Physiol.24;518-528,1968.

104.Davis,J.A.M,H.Frank,b.j.Whipp,and K.Wasserman.Anaerobic threshold alterations caused by endurance training in middle aged men J.Appl.Physiol.46;1039-1046.1979.

105.Bijker KE,de Groot,Hallander AP.Differences in leg muscle activity during running and cycling in humans.Eur J Appl Physiol 2002 Oct;87(6);556-61.

106. Wiswell RA,Girandola RN,and De Vries HA;Comparison of anaerobic threshold on bicycle and treadmill.Med Sci Sports 11:88,1979.

107.Rice,A.J.,G.C.Scroop,A.T.Thornton,N.S.McNaughton,K.J.Rogers,M.J.Chapman,H. W.Greville,R.Scicchitano and C.J.Gore,2000.Arterial hypoxaemia in endurance athletes is greater during running than cycling.Respir Physiol.,123:235.

METABOLIC AND CARDIO RESPIRATORY RESPONSES BETWEEN TREADMILL AND ERGOMETER CYCLE

PROFORMA

Name	:	
Age	:	
Sex	:	
Address	:	
Present History	:	
Past History	:	H/o DM, HT, Asthma, TB, any injuries
Menstrul History	:	Regular / Irregular
Obstetrics History	**:**	**LCB -** **LMP -**

General Examination :

Anaemia	-	Present/Not Present
Cynosis	-	Present/Not Present
Clubbing	-	Present/Not Present
Lymphadenopathy	-	Present/Not Present

Vital signs - RR / min HR /min BP -mmhg

Antheropometry :

Height - Weight - BMI -

Systemic Examination:

Examination of CVS and RS :

Inspection :

Position of trachea

Apex beat : Visible / Not visible

Shape of the chest:

JVP

Palpation:

Position of trachea

Location of Apex beat

Chest expansion

Vocal fremites

Location of thrill (if any)

Auscultation :

S1, S2

Any murmers / added sounds

Character of breath sounds

Other System Examination :

Parameters :

	MHR		VO2$_{max}$		Pre Exercise BP				Post Exercise BP				Blood lactate	
	Ist wk	**XIIth wk**	**Ist wk**	**XIIth wk**	**Ist wk**		**XIIth wk**		**Ist wk**		**XIIth wk**		**Ist wk**	**XIIth wk**
					Sys	**Dia**	**Sys**	**Dia**	**Sys**	**Dia**	**Sys**	**Dia**		
Treadmill														
Ergometer Cycle														

Informed Consent :

I__________ have been explained about the procedure in my own language. I consent voluntarily to participate as a participant in this procedure.

Signature of the Participant

ABBREVIATIONS USED IN THIS STUDY

AT – Anaerobic threshold

BP - Blood Pressure

DBP - Diastolic blood pressure

EC - Ergometer cycle

HR - Heart rate

MHR - Maximal heart rate

RHR - Resting Heart rate

RPM - Revolution Per Minute

SBP - Systolic blood pressure

TM - Treadmill

VO_2 max - Maximal aerobic power

WHO - World Health Organization

CONSENT FORM

Dr,---,Post Graduate student in the department of Physiology, Thanjavur Medical College, Thanjavur is studying the cardiorespiratory and metabolic responses of Treadmill and Ergometer cycle in healthy females. The test procedures are explained to me clearly. I understand the risks involved in the above procedure. I hereby give my consent to participate in this study. The data obtained here may be used for research and publication.

Signature:

Name:

Place:

MASTER CHART

S.No	Exercise	Age	HT	Wt		RHR	MHR	Vo2Max	BP				Blood Lactate	
				1 wk	12wk				Pre SBP	Post SBP	Pre DBP	Post DBP	Pre	Post
1	TM	35	151	56	55	72	168	35	90	100	60	60	9.12	30
2	TM	31	157	87	86	86	164	28.6	120	124	84	80	13.1	28.2
3	TM	37	150	53	53	89	166	27.97	110	112	80	76	10.1	26
4	TM	26	160	66	64	78	170	32.9	120	126	80	76	13	33
5	TM	39	155	70	68	84	168	30	130	140	80	80	19	35
6	TM	33	153	53	50	72	165	34.37	124	128	82	80	12	40
7	TM	21	147	65	64	78	162	31.15	114	120	70	66	11.2	30
8	TM	32	150	60	60	83	158	28.55	126	124	80	78	13.2	32.2
9	TM	26	156	64	63	88	158	26.93	110	114	76	70	9.3	28
10	TM	32	148	55	54	73	170	34.93	110	110	70	70	13.8	24
11	TM	37	153	51	51	84	166	29.64	110	114	80	80	10.1	21
12	TM	34	156	62	62	72	181	34.36	126	130	78	76	6.93	24
13	TM	20	152	53	52	74	169	34.25	94	100	60	60	12.1	23.33
14	TM	32	152	58	57	82	170	31.09	110	120	70	68	10.3	32
15	TM	23	156	58	56	84	171	30.53	120	118	66	60	11.1	32.3
16	TM	19	145	47	46	74	165	33.44	90	100	60	60	9.2	38
17	TM	26	156	60	58	90	166	27.6	96	116	60	60	7.2	33
18	TM	33	153	58	58	84	167	29.82	100	120	70	66	10.1	30
19	TM	35	161	62	61	88	164	27.95	100	112	66	66	11	33.4
20	TM	31	160	66	64	83	166	30	110	116	74	70	9	32

S.No	Exercise	Age	HT	Wt		RHR	MHR	Vo2Max	BP				Blood Lactate	
				1 wk	12wk				Pre SBP	Post SBP	Pre DBP	Post DBP	Pre	Post
21	EC	30	152	56	53	72	150	31.25	80	120	60	60	16.6	58
22	EC	27	153	62	62	78	152	29.23	100	130	80	76	12.2	62
23	EC	30	159	66	64	84	144	25.71	96	126	60	60	14.1	66
24	EC	28	154	55	55	88	148	25.22	100	130	70	66	11.2	68
25	EC	30	150	54	52	92	143	23.31	110	136	72	70	13.7	69
26	EC	20	152	52	51	88	146	24.88	9	124	60	60	10.1	60
27	EC	35	150	59	58	86	145	25.29	100	130	70	70	12	66
28	EC	31	148	53	54	88	160	27.27	120	146	80	74	10.2	68
29	EC	30	142	52	52	88	158	2.93	100	132	70	70	8.1	69.2
30	EC	34	143	50	50	84	154	27.5	90	124	0	60	9.2	66.4
31	EC	28	148	55	53	88	159	27.1	112	128	80	76	12.1	69
32	EC	31	159	55	53	86	167	29.12	110	140	80	78	13.6	64
33	EC	28	145	53	53	84	172	30.71	110	130	70	70	12.2	66.4
34	EC	33	152	55	54	76	156	30.59	96	124	60	60	13.5	88.12
35	EC	31	155	54	54	78	158	30.38	112	136	70	70	10.3	70.83
36	EC	27	151	58	57	83	171	30.9	100	150	70	60	10.2	68
37	EC	32	153	55	54	86	173	30.17	110	144	68	66	12.1	66
38	EC	33	150	52	51	84	155	27.67	100	136	70	68	17	66
39	EC	28	151	51	51	86	149	25.98	130	152	80	72	13.2	70.2
40	EC	19	154	48	47	80	171	32.06	96	120	60	54	14.1	80